Site Investigation Report

Hog Island Inlet

City of Superior, Douglas County, Wisconsin

SEH No. WIDNR9905.02

September 2003

SHORT ELLIOTT HENDRICKSON INC
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Site Investigation Report
Hog Island Inlet
City of Superior, Douglas County, Wisconsin

Prepared for:
Wisconsin Department of Natural Resources

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I, Mark J. Broses, hereby certify that I am a registered professional engineer in the State of Wisconsin, registered in accordance with the requirements of ch. A-E 4, Wis. Admin. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A-E 8, Wis. Admin. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable regulations in chs. NR 700 to 726, Wis. Admin. Code.

#31176 — 9/29/03

Mark J. Broses, PE — PE Number — Date
Project Manager

I, Gloria Chojnacki, hereby certify that I am a Scientist as that term is defined in s. NR 712.03(3) Wis. Admin. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Admin. Code

9/29/03

Gloria C. Chojnacki, CHMM — Date
Environmental Scientist

I, John E. Guhl, hereby certify that I am a Hydrogeologist as that term is defined in s. NR 712.03(1) Wis. Admin. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Admin. Code.

John E. Guhl — #120 — 9/29/03

John E. Guhl, PG — PG Number — Date
Hydrogeologist

Executive Summary

This investigation report was prepared by Short Elliott Hendrickson Inc. (SEH) on behalf of the Wisconsin Department of Natural Resources (WDNR) Bureau of Remediation and Redevelopment, per WDNR contract dated June 13, 2002 (which authorized work to begin on July 1, 2002). Site investigation activities outlined herein are in general accordance with ch. NR 716, Wisconsin Administrative Code, WDNR's February 28, 2002 revised scope of work, and the tasks described in SEH's April 10, 2002 proposal.

The Newton Creek/Hog Island system is located in Superior, Wisconsin. The headwaters of Newton Creek begin at the Murphy Oil USA (Murphy) Refinery treated wastewater impoundment and flows approximately 1.5 miles to Hog Island Inlet, at the southeast end of Superior Bay, Lake Superior. The current study focused on Hog Island Inlet and Segment L of Newton Creek.

This report describes the results of the site investigation and risk evaluation conducted by SEH and its subcontractors.

Field Activities

Field sampling activities conducted in Segment L of Newton Creek and Hog Island Inlet, included:

- Field screening to delineate visible contamination;
- Floodplain soils and sediment sampling in Newton Creek Segment L;
- Shoreline soils and sediment sampling in Hog Island Inlet;
- Reference shoreline soils and sediment samples collected adjacent to Loons Foot Landing;
- Surface water sampling in Hog Island Inlet and adjacent to Loons Foot Landing;
- Collection of sediment cores in Hog Island Inlet and Loon's Foot Landing for macroinvertebrate population surveys;
- A study of ultraviolet light intensities was conducted at the site to determine typical ultraviolet light intensity at various water depths and during various weather conditions; and
- Collection of large-volume (20-gallon) sediment samples in Hog Island Inlet and Loons Foot Landing for toxicity analysis. The homogenized sediment samples were utilized in standard toxicity tests conducted with laboratory populations *of Hyalella azteca, Lumbriculus variegatus*, and *Chironomus tentans*. In parallel tests, the organisms were exposed to UV light intensities similar to those at the site.

Contaminant Distribution, Fate, and Transport

PAH concentrations in sediments appear to have stayed consistent with the WDNR's 1993 and 1994 sampling results reported in 1995. Differences in DRO results between the sampling events may be related to the analytical methodologies used by the different laboratories involved rather than to actual changes in concentrations over time of DRO in the sediments. Generally, the surficial sediments (0-0.5 ft) do not appear to be less contaminated than deeper sediments (0-4 ft). Natural attenuation of contaminated sediments does not appear to have occurred since the WDNR's previous

field study in 1994. Natural attenuation of the contamination is expected to be a very minimal over a long period of time.

Visual identification of contaminated sediments (e.g., based on coloration and/or presence of sheens when disturbed) appears to be reasonable based on the sampling conducted. Sediments in Segment L are visually contaminated. The area of visually contaminated sediments in Hog Island Inlet is mainly in the central and northwestern end, which includes but is greater than the 1995 proposed area of remediation. Scattered areas of visually contaminated sediments exist throughout the inlet, beyond the 1995 proposed remediation area.

Sediment-associated contaminants are easily suspended into the water column during disturbance activities.

Human Health Risk

The supplemental human health risk assessment indicates that risks may exceed target risk levels. Risks are primarily due to exposure to the surface water with suspended sediment contaminants from the area of visually identified contaminated sediments.

Current calculated risks are higher than those originally calculated in the 1995 WDNR study. The increase is primarily based upon the consideration of PAH compounds that were previously not considered due to data quality considerations.

Ecological Risk

Integration and evaluation of the evidence from the supplementary ecological risk assessment indicates that it is highly likely contamination identified in Hog Island Inlet sediments pose ecological risks to the benthic macroinvertebrate community. This is consistent with the 1995 WDNR study conclusions. Evidence includes sediment chemistry, toxicity study results, and benthic macroinvertebrate community metrics.

Toxicity test results indicate that sublethal ecologically undesirable impacts to the benthic community begin at threshold TPAH concentrations greater than 2 to 3 mg/kg. Acute impacts appear to occur at TPAH concentrations greater than 5 to 7.5 mg/kg. Toxicity study results indicate that photo-activated toxicity increased with exposure to ultraviolet light in the laboratory that simulated ultraviolet light levels measured in the field at Hog Island Inlet.

A strong dose response relationship appears to exist between PAH chemical concentrations and toxicity test results. There is also a strong relationship between PAH chemical concentrations and macroinvertebrate study results.

There is a strong positive relationship between PAH concentrations and the measurements for DRO and total expanded hydrocarbons. Likewise there is a strong relationship between PAH concentrations and the ecologically based sediment guideline values (Probable Effect Concentration Quotients and PAH Equilibrium Partitioning Sediment Quality Guideline Toxic Units.)

The Biotic Index metric for benthic community structure indicates that each study location in Hog Island Inlet is severely polluted as it relates to organic pollution. It is believed that a large portion of the organic pollution present at Hog Island Inlet sites originates in residual petroleum hydrocarbons compounds. The reference location in Loon's Foot Landing appears to support a benthic community that is associated with somewhat less organic pollution based on the Biotic Index metric and other metrics. The dual effects of stimulation of a pollution tolerant populations and toxic effects to benthic organisms based on the particular mixture of petroleum hydrocarbons present needs to be taken into account in regard to the benthic metrics.

Contaminant presence leading to adverse biological effects related to degradations and alteration of the benthic community structure is evident. Bioaccumulation of sediment-associated contaminants has the potential to adversely affect upper trophic level aquatic life and aquatic dependant wildlife.

Impacts to benthic organisms and immature fish are expected to present the highest risks.

Cleanup Goals and Remediation Volumes

The overall cleanup goals for Hog Island Inlet should consider ecological risks, human health risks, and contaminant transport mechanisms. Remediation options for the contaminated sediment of the creek should be designed to achieve an established science-based sediment quality objective protective of human health or aquatic life to the extent practicable. Practicality in achieving the sediment quality objectives is defined by considering net environmental effects, including health, safety and welfare, natural recovery rates, engineering feasibility, costs, and compliance with applicable laws and regulations.

Visual identification of contamination is reasonable for contamination associated with acute-related ecological risks, but not for chronic ecological protection. If cleanup goals are based on human health and/or acute ecological protection (5 to 7.5 mg/kg TPAH), the visually contaminated sediment volumes for remediation would be approximately 20,000 cubic yards. If cleanup goals are based on chronic ecological protection (2 to 3 mg/kg TPAH), the sediment volumes for remediation would likely be approximately 40,000 cubic yards. Cleanup goals based on aesthetic values (odors) for future uses such as recreational swimming may result in higher cleanup volumes.

List of Abbreviations

Abbreviations used in Site Investigation Report

ANSRI	Area of Special Natural Resource Interest
AOC	Area of Concern
ATSDR	Agency for Toxic Substance and Diseases Registry
AVS	Acid Volatile Sulfides
BI	Biotic Index
BOD	Biological Oxygen Demand
CCC	Criterion Continuous Concentration (chronic)
Cd	Cadmium
cfs	cubic feet per second
cm	centimeter
COD	Chemical Oxygen Demand
City	City of Superior
COPC	Chemicals of Potential Concern
Cr	Chromium
Cr+6	Hexavalent Chromium
Ct	*Chironomus tentans* (midge species)
Cu	Copper
DRO	Diesel Range Organics
DW	Dry Weight
EPA	Environmental Protection Agency (USEPA)
ERA	Ecological Risk Assessment
ESG	Equilibrium Partitioning Sediment Guidelines
ESG TUs	ESG Toxic Units
FCV	Final Chronic Value
FID	Flame Ionization Detector
GPS	Global Positioning System
Lv	*Lumbriculus variegates* (oligochaete or worm species)
HAH	Heterocyclic Aromatic Hydrocarbon
Ha	*Hyalella azteca* (amphipod or scud species)
HEAST	USEPA Health Effects Assessment Summary
Hg	Mercury
HHRA	Human Health Risk Assessment
HI	Hazard Index
HI Inlet	Hog Island Inlet
HQ	Hazard Quotient
IRIS	USEPA Integrated Risk Information System
LOEC	Lowest Observed Effect Concentration
LOEL	Lowest Observed Effects Level
LSRI	Lake Superior Research Institute
mg/kg	milligram/kilogram
mg/l	milligram/liter
MPCA	Minnesota Pollution Control Agency
Murphy	Murphy Oil USA
MSL	Mean Sea Level
NAPL	Non Aqueous Phase Liquids
NAWQC	National Ambient Water Quality Criteria
NC	Newton Creek

List of Abbreviations (Continued)

Ni	Nickel
NOEL	No Observed Effect Level
NRWQC	National Recommended Water Quality Criteria
O&G	Oil and Grease
ORNL	Oak Ridge National Lab
p	p value as it relates to statistical significance
PAH	Polynuclear or Polycyclic Aromatic Hydrocarbons
PAT	Photo Activated Toxicity
Pb	Lead
PEC	Probable Effects Concentration
PEC-Q	PEC Quotient
PRBG	Preliminary (Human Health) Risk Based Remediation Goal
r2	Coefficient of Determination, r-squared
RCL	ch. NR 720 Residual Contaminant Level
RfD	Reference Dose
RME	Reasonable Maximum Exposure
SADA	Spatial Analysis and Decision Assistance software
SD	Standard Deviation
SEL	Severe Effects Level
SEM	Simultaneously Extracted Metals
SEH	Short Elliott Hendrickson Inc.
SF	Slope Factor
SPE	Solid Phase Extraction
State	State of Wisconsin
SW Index	Shannon Weiner Diversity Index
SQT	Sediment Quality Target
TEC	Threshold Effect Concentration
TEH	Total Expanded Hydrocarbons (PAH and Alkyl Substitutes)
TOC	Total Organic Carbon (as Non-Purgeable Organic Carbon)
TPAH	Total PAHs
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
µg/kg	microgram/kilogram
µg/l	microgram/liter
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
VOC	Volatile Organic Compound
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollution Discharge Elimination System
Wis. Admin. Code	Wisconsin Administrative Code
Zn	Zinc

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Site Investigation Report

Hog Island Inlet

Prepared for Wisconsin Department of Natural Resources

1.0 General Information

This investigation report was prepared by Short Elliott Hendrickson Inc. (SEH) on behalf of the Wisconsin Department of Natural Resources (WDNR) Bureau of Remediation and Redevelopment, per WDNR contract 02RRSU dated June 13, 2002 (which authorized work to begin on July 1, 2002). Site investigation activities outlined herein are in general accordance with ch. NR 716, Wis. Admin. Code, WDNR's February 28, 2002 revised scope of work, and the tasks described in SEH's April 10, 2002 proposal.

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This report describes the results of the site investigation and risk evaluation conducted by SEH and its subcontractors.

1.1 Project Contacts

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1.2 Project Goals

Several goals were established for this phase of the project including:

- Document the horizontal and vertical extent of sediment and flood plain soils contamination in and adjacent to Hog Island Inlet and Newton Creek Segment L;
- Develop risk-based cleanup goals for contaminated sediments in Hog Island Inlet; and
- Document remedial action options for Newton Creek Segment L and Hog Island Inlet.

1.3 Scope of Work

Several tasks were conducted by the project team during this phase of the project, focusing on the Hog Island Inlet. The scope of work included the following tasks:

Newton Creek Segment L and Hog Island Inlet Tasks

- Field Investigation – Newton Creek Segment L and Hog Island Inlet **(Task 4)**
- Supplementary Ecological Risk Assessment (ERA) – Hog Island Inlet **(Task 5)**
- Supplementary Human Health Risk Assessment (HHRA) – Hog Island Inlet **(Task 6)**
- Site Investigation Report – Newton Creek Segment L and Hog Island Inlet **(Task 8)**
- Remedial Action Options – Feasibility Study Report – Newton Creek Segment L and Hog Island Inlet **(Task 10)**

1.4 Site Description

The Newton Creek/Hog Island system is located in the City of Superior, Wisconsin. Figure 1, " Site Location Map" illustrates the general location of the system. The current study area includes Segment L of Newton Creek and the Hog Island Inlet, as shown on Figure 2, "Sediment and Soil Sampling Locations." The study area is located in the SE 1/4 of Section 25, T49N, R14W, Douglas County, Wisconsin.

The Newton Creek/Hog Island system is defined by the WDNR as including the surface water environment encompassing Newton Creek Impoundment, Newton Creek, Hog Island Inlet, the inlet mouth to Superior Bay, and all floodplain, overflow areas, and wetlands associated with these water bodies. The Newton Creek/Hog Island system receives storm water through overland flow and storm water

outfalls. The primary non-storm water source of surface water to the Newton Creek/Hog Island system is the Murphy Refinery treated process wastewater outfall (permitted as Outfall #1 in WPDES Permit No. WI-0003085-6).

Under normal conditions (without runoff from seasonal thaws or precipitation events), creek flows from the impoundment at a rate of approximately one cubic foot per second (cfs). Normal creek width is approximately three feet and creek water depth varies from six inches to one foot. However, storm events significantly increase creek flow for short periods.

According to s. NR 104.10(3)(b): "Newton Creek in the City of Superior, from the headwaters to its mouth into Hog Island Inlet of Superior Bay [is] classified as a non-continuous stream and [is also] classified for fish and aquatic life uses with the subcategory of limited forage fish communities. Hog Island Inlet and Superior Bay [are] classified for fish and other aquatic life uses with the subcategory of Great Lakes communities."

The Newton Creek/Hog Island system and its contiguous wetlands encompass approximately 60 acres with the total length of the system extending approximately 1.5 miles. Newton Creek flows through numerous culverts and under bridges that exist where the creek intersects roadways and a railroad line. It flows through industrial, commercial, and residential areas in the City of Superior before reaching Hog Island Inlet. Newton Creek is generally accessible to the public, along its entire length.

Adjacent properties in the Segment L area are a mixture of undeveloped/vacant land with nearby residential areas. The Osaugee Recreational Trail runs parallel to the Hog Island Inlet shore and crosses Newton Creek via a pedestrian bridge. In the Hog Island Inlet area, the surrounding land use is a mixture of undeveloped and vacant industrial properties. Appendix A, "Photographs" includes photos in the vicinity of Segment L and the Hog Island Inlet.

The 1994 WDNR investigation of Newton Creek subcategorized Newton Creek into 12 segments (A through L), with Segment A being the most upstream section of the creek (downstream from the impoundment), and Segment L being the most downstream section of the creek before it discharges into Hog Island Inlet. Appendix B, "Background Data" includes an excerpted figure illustrating the various segment locations.

This investigation focused on Segment L and the Hog Island Inlet. Additional descriptive information is provided for Segment L and the Hog Island Inlet, below.

1.4.1 Segment L

As shown on Figure 2, Segment L begins where the creek emerges from beneath Highway 2, on the northeast side of the highway. Segment L extends approximately 600 feet from the highway, and discharges directly into the Hog Island Inlet.

Property on both sides of Segment L, are owned by the City of Superior. The land is undeveloped. Tracks of the Burlington Northern Santa Fe Railroad bound the City parcels to the north and south. There are no residences located along Newton Creek in Segment L.

The Segment L floodplain is heavily vegetated with invasive wetland vegetation, primarily grasses and forbs, with a few alders and poplar trees. Appendix A includes photos of the area in the vicinity of Segment L.

Normal flow into Newton Creek is from Murphy's treated wastewater discharge upstream, via the up gradient creek segments. During storm events, storm water also flows into the creek from approximately ten storm water outfalls, minor drainage-ways and overland flow.

1.4.2 Hog Island Inlet

As shown on Figure 2, Hog Island and Hog Island inlet together form an approximately 90-acre embayment in Superior Bay. Hog Island is approximately 55 acres and is connected to the mainland shore by a wetland isthmus 20 acres. Hog Island Inlet covers approximately 15 acres. An approximately 50-foot wide channel in the northwest corner of the embayment opens into Superior Bay. Hog Island Inlet's mouth is approximately 1.4 miles from the Superior Bay entry in Lake Superior.

Hog Island was formed by the historic deposition of dredge materials from the adjacent shipping channel of Superior Bay. The dredge materials have been largely undisturbed and now support a diverse wetland ecosystem around along the southwestern side of the island. The central part of the island would be considered upland without plants or soils characteristic of wetlands.

Hog Island Inlet is bordered by Hog Island, the Lakehead Pier, the Hog Island wetland isthmus, and the mainland shore. Hog Island is undeveloped. The wetland isthmus is likewise undeveloped. The Lakehead Pier was developed at one time but is currently vacant. The pier may have been used for transfer and storage of various materials including iron, coal, and/or oil. A series of parallel railroad tracks lie along the southwest side of the Inlet. State Highway 2 runs parallel to the railroad tracks and mainland shore at higher elevations.

Water depths in Hog Island Inlet range from less than one foot to seven feet. The shallowest water depths occur in the east end of the inlet and the deepest near the inlet opening to Superior Bay. Water level changes in Superior Bay produce short term variations in water level up to 0.5 feet or more in the inlet due to Lake seiche effect. As water levels fall in Lake Superior, water flows out of Hog Island Inlet into Superior Bay. As water levels rise, water flows into Hog Island Inlet from Superior Bay.

The surface water elevation of Lake Superior currently varies between approximately 601 and 602 feet above mean sea level (MSL). The elevation of the lake varies seasonally with lower elevations February to March and higher elevations in August to September. The recent annual surface water elevation is approximately seven inches lower than its long-term average. Appendix C, "Surface Water Elevation Data" includes recent and historical data on surface water elevations.

Based on bottom probing, soft sediment in the inlet is less than one foot thick through most of the eastern half of the inlet and near shore around most of the western half of the inlet. Sediments greater than two feet thick cover approximately one half of the western portion of the inlet. In a few relatively small areas, the soft sediment thickness exceeds three feet.

There are no residences adjacent to the Hog Island Inlet. Several residences are located approximately 300 feet to the south with commercial establishments to the west along Hwy 2. Local residents use the island and wetland isthmus areas for recreation.

According to the 1993-1994 wetland survey (Reed, 1994) and the WDNR (WDNR, 1994), the dominant vegetation encountered around the southwestern side of Hog Island Inlet is classified as an emergent plant community. The dominant plant species included Burreed (*Sparganium sp.)*, Lake sedge *(Carex lacustris)*, and Broad-leaved cattail. *(Typha latifolia).* The wetland isthmus and Hog Island perimeter wetland vegetation is characteristic of emergent marsh, sedge meadow and shrub-carr/alder thicket with scattered lowland hardwoods. Submergent and floating leaf aquatic plant species are present in the open waters of the inlet beyond the emergent vegetation stands. Appendix A includes photos of the Hog Island Inlet area.

Hog Island and the nearby Ogdensburg Pier (also called Lakehead Pier) serve to protect the Hog Island Inlet from wave action, creating an aquatic environment that supports a diverse aquatic community.

Hog Island Inlet has a high functional value for aesthetics/ recreation/education and science. Although the ecosystem of Hog Island Inlet is the result of dredge spoil deposition, the area has been allowed to develop naturally. The area hosts a wide diversity of plant

species and has future potential as an educational study site or outdoor laboratory. The Inlet is already used by the USEPA and others for scientific study. All wetlands within the project area including those in Hog Island Inlet are part of the Lake Superior Areas of Special Natural Resource Interest (ASNRI) as listed in NR 103.04 Adm. Code. ASNRI are recognized by the state or federal government as possessing special ecological, cultural, aesthetic, educational, recreational, or scientific qualities.

Hog Island Inlet is part of the "nearshore zone area" of Lake Superior that serves important functions in maintaining the biodiversity of the Lake system. Nearshore areas like Hog Island Inlet represent only 5% of the total area of Lake Superior. Virtually all species of Great Lakes fish use the nearshore waters for one or more of their critical life stages or functions (e.g., permanent residence; migratory pathway for anadromous fish; temporary nursery and feeding grounds; and refuges for young-of-the year fish) (SOLEC, 1997).

Researchers with United States Environmental Protection Agency (USEPA) have identified a wide variety of species, various life stages (young-of-the-year, yearling, and adult) and abundance of fish in the Inlet (Tanner 2003). Twenty-four species of fish were collected in the Inlet in fyke nets by USEPA. Seventeen of the twenty four were in the young-of-the year life stage. Game fish collected included yellow perch, walleye, northern pike, small mouth bass, bluegill, and rock bass. WDNR fisheries staff observations are that the Inlet appears to support northern pike spawning habitat, and both adult and young of the year pike have been observed.

The habitat in the Inlet appears similar to the outer marsh habitat of nearby Allouez Bay. Generally, young-of-year yellow perch had the highest number caught followed by emerald shiners and spottail shiners. This is similar to the Allouez Bay ordering of abundant species (Brazner et al., 1998). Hog Island Inlet did not have high numbers of brown bullhead or silver redhorse as found in Allouez Bay. This may be due to sampling only in August in the Inlet. The Eurasian ruffe shows up in a number of fyke-net samples in the Inlet but in relatively low numbers. It was found in greatest numbers in the outer marsh of Allouez Bay. Since the Inlet habitat is similar to the outer marsh habitat, it is expected that the ruffe would be found in the inlet. Brazner et al. (1998) noted for Allouez Bay findings that the catch primarily reflected young fish, and like other Great Lakes coastal wetlands (such as Hog Island Inlet), it serves as an important nursery for many Great Lakes fish.

1.5 Regional Physical Information

This section provides general information regarding the regional topography, hydrology, geology, and hydrogeology in Superior, Wisconsin.

1.5.1 Topography and Physiography

The City of Superior area consists of two distinct physiographic areas resulting from different forms of glacial deposition in the area. The northern portion is comprised of the Superior Lowlands. This area was submerged during higher stages of Lake Superior. The Superior Lowlands are characterized by flat to undulating topography underlain by thick red lacustrine clay. The southern portion of the Superior region consists of uplands characterized by rolling, hilly topography. This area is typically underlain by sandy till and by sand and gravel deposited as outwash by preglacial rivers.

Newton Creek is located in the Superior Lowland. The topography of this area is relatively flat, with a gentle regional slope to the north-northwest toward Lake Superior.

1.5.2 Hydrology

Average annual precipitation in the Superior vicinity is approximately 28 inches. Approximately 60% of the precipitation re-enters the atmosphere through evapotranspiration, with the remainder either entering surface water as runoff or infiltrating into groundwater (Young, 1974).

Direction and volume of surface runoff varies with location. Surficial soils in the region are poorly drained due to the underlying clay soils, which limit infiltration. Wetlands capture a large portion of the precipitation where the topography is relatively flat.

1.5.3 Geology

The Superior area is characterized by the bluffs of easily eroded red clay, which serves as a major source of fine-grained lake sediment. The combination of easily eroded clay bluffs and northern exposure make the Wisconsin shore a major sediment source area. Ancestral lake Superior is known as Lake Keweenaw. The ancestral lake had an elevation of 780 feet (nearly 180 feet above the current Lake Superior level). The thick deposits of red clay that form the Superior Plain is accumulated at the bottom of Lake Keweenaw.

A relatively thick sequence of unconsolidated Pleistocene deposits overlies Precambrian or Cambrian sandstone bedrock in the Superior area. The thickness of unconsolidated deposits ranges from less than 10 feet in Duluth to approximately 600 feet in the drowned valley of the St. Louis River Valley. The thickness of the unconsolidated deposits is controlled by bedrock topography and surface topography.

Surficial soils in the vicinity of the area consist of the Ontonagon-Rudyard Complex, Ontonagon silty clay loam, and Rudyard-Bergland clay soils. These are moderately well drained to poorly drained soils formed in clayey lacustrine deposits. Soils located in areas of steep slopes are highly erodible (USDA, 1984).

Surficial soils in the vicinity of the site are underlain by a thick sequence of glacial till and offshore lacustrine soils belonging to the Miller Creek Formation. The soils comprising the Miller Creek Formation typically consist of thick unlaminated reddish-brown clay layers. The Miller Creek Formation is divided into two members B the Douglas Member and the underlying Hanson Creek Member. The two members are similar to one another. The Douglas Member is typically somewhat clayier and redder in color (Clayton, 1984). The Douglas Member typically consists of approximately 10% sand, 26% silt, and 64% clay. The Hanson Creek Member typically consists of approximately 10% sand, 32% silt, and 58% clay (Mickelson, 1984).

The Miller Creek Formation is underlain by the Copper Falls Formation. The Copper Falls Formation largely consists of fluvial sand and gravel and till. The Copper Falls till deposited in Douglas County contains an average of 70% sand, 25% silt, and 5% clay (Mickelson, 1984). The Copper Falls Formation has not been encountered in the soil borings performed on the site. Therefore, the thickness of the Copper Falls Formation and the underlying Miller Creek Formation at this location has not been determined.

The Pleistocene deposits in the Superior vicinity are underlain by Cambrian to Precambrian sedimentary deposits of the Bayfield Group and potentially the Oronto Group. The Bayfield Group consists largely of nearly flat-lying quartz sandstones. The Oronto Group (where present) consists of shales and arkosic sandstones. The sedimentary bedrock deposits in the Superior area are underlain by Precambrian volcanic or crystalline deposits. The thickness of sedimentary bedrock in the Superior vicinity has not been determined (Roshardt, 1976).

1.5.4 Hydrogeology

Two major aquifers are present in the vicinity of Superior; the sand and gravel aquifer and the sandstone aquifer. The sand and gravel aquifer occurs in either surficial sand and gravel deposits or in buried deposits of sand and gravel. Buried sand and gravel deposits can be present on the bedrock surface or within ground or end moraines (Young, 1974). Yields from the sand and gravel aquifer in the Superior area range from less than 10 gallons per minute (southeast of Superior) to 500 gallons per minute (on Wisconsin Point and Minnesota Point). Regional direction of shallow groundwater flow is generally to the north (toward Lake Superior), but is locally influenced by topography and surface drainage patterns.

The sandstone aquifer is comprised of the sandstone and shale deposits of the Bayfield and Oronto Groups. The Bayfield Group is generally more productive than the Oronto Group because the latter is shaley. Yields from the sandstone aquifer in the Superior area are typically between 50 and 150 gallons per minute (Young, 1974).

The Miller Creek Formation in the Superior area is typically a low-permeability unit with hydraulic conductivities on the order of $1x10^{-8}$ cm/sec. Average downward linear velocities of groundwater in the Miller Creek Formation is less than 0.5 cm/year. Because of these permeability's, vertical recharge to the underlying Copper Falls Formation through the Miller Creek Formation is minimal. Tritium analysis of groundwater from within the Miller Creek Formation indicates groundwater below three meters was recharged to the formation prior to the 1950's. A majority of pore water within the Miller Creek Formation is very old, possibly dating from deposition approximately 10,000 years ago (Bradbury, 1985).

1.5.5 Regional Water Quality

Most groundwater in the region is of good quality and is usable for most purposes. The main chemical constituents in solution in most regional groundwater are calcium, magnesium, and bicarbonate. Hardness is directly proportional to the concentration of dissolved solids in groundwater when the dominant ions are calcium and magnesium. However, the groundwater at some locations contains high concentrations of sodium, chloride, or sulfate ions (Young, 1974).

Regionally, concentrations of dissolved solids in groundwater are lowest in recharge areas where infiltration rates and groundwater velocities are relatively high (coarse grained soils). Dissolved solids are generally highest in discharge areas in the Superior Lowland, where groundwater velocities are low, and contact time with the large surface area of clay particles is long.

In general, groundwater present within the regional unconsolidated deposits is not highly mineralized. Concentrations of dissolved solids are generally less than 400 mg/l in Douglas County. Concentrations of dissolved iron and manganese are quite variable in the region. Naturally occurring concentrations of these substances commonly exceed the recommended drinking water standards for iron and manganese (0.3 mg/l and 0.05 mg/l, respectively). Concentrations of these substances at levels exceeding the standards may be objectionable due to taste or aesthetics, but have not been found to produce adverse health effects.

Regional surface water quality is generally good except for high sediment yields in areas where the Miller Creek Formation is present. The concentration of dissolved mineral content is generally low.

Primary dissolved constituents are typically calcium, magnesium, and bicarbonate. The chemical quality of regional surface water is similar to groundwater found in the regional glacial drift (Young, 1974).

2.0 Historical Review

The Newton Creek/Hog Island Inlet system has been the focus of WDNR investigations for several years. SEH reviewed information from the WDNR files in the compilation of this background section including, but not limited to: summary reports, field sampling plans, field notes, laboratory reports, project memorandums, and environmental permits. The historical review contained herein, focuses on Hog Island Inlet and potential contaminant source areas.

Previous summary reports that were reviewed by SEH in preparation of this report are listed below in chronological order:

- Identification of Pollutants of Concern, Further Needed Site Assessments, and Estimated Remediation Costs for Contaminated Sediments in Newton Creek, Hog Island Inlet, and Potentially, Superior Harbor, WDNR, April 6, 1992;
- Quality Assurance Project Plan – Characterization of Contamination in Newton Creek System Habitats Potentially Impacted by the Murphy Oil Refinery Effluent Discharge and Other Dischargers, WDNR, June 1993.
- Newton Creek/Hog Island Inlet Investigative Survey, Eder Associates Consulting Engineers (for Murphy), November 1993;
- Evaluation of Sediment Contamination at Newton Creek and Hog Island Inlet, ENSR Consulting Engineers (for Murphy), December 1993;
- Human Health Risk Assessment for Newton Creek and Hog Island Inlet, ENSR (for Murphy), August 1994;
- Assessment of Wetland Habitats Associated with the Newton Creek System, Don Reed (for WDNR), November 23, 1994;
- Characterization of Sediment Contamination in the Newton Creek System, WDNR, December 15, 1994;
- DRAFT RCRA 3008(h) Consent Order to Murphy Oil USA, Inc., Superior, Wisconsin Facility. USEPA ID No. WID 816 194 336. USEPA, March 01, 1995 DRAFT;
- Summary of Investigation Activities Associated with the WDNR Newton Creek Feasibility Study Supplementary Site Characterization, Burns & McDonnell (for Murphy), March 1995;
- Remedial Alternatives Array Document for Newton Creek System, RMT (for WDNR), April 1995;

- Feasibility Study Report for Newton Creek System, RMT (for WDNR), October 1995;
- Newton Creek System Sediment Contamination Site Characterization Report, WDNR, December 1, 1995;
- Results of Aerobic Biodegradation Screening Treatability Study for the Newton Creek System, RMT (for WDNR), January 1996;
- Closure/Post-Closure Plan for Wastewater Treatment Ponds Nos. 1 & 6, Wisconsin Petroleum Refinery, Murphy Oil USA, Inc., Burns & McDonnell (for Murphy), June 1996; and
- Superior Refinery Pond Closure Project Final Workplan for Newton Creek Remediation, Roy F. Weston (for Murphy), August 1997.
- Site Investigation Report - Newton Creek Segments B and C, SEH (for WDNR), September 2000.
- Preliminary Engineering Report – Newton Creek Remediation, SEH (for WDNR), November 2001.
- Site Investigation Work Plan – Newton Creek and Hog Island Inlet, SEH (for WDNR), August 2002.
- Remedial Investigation Report – Newton Creek, SEH (for WDNR), February 2003
- Remedial Action Options Report – Newton Creek, SEH (for WDNR), April 2003
- Remedial Design Report – Newton Creek, SEH (for WDNR), April 2003

2.1 Project History

The WDNR initiated a sediment investigation of Newton Creek and Hog Island Inlet in 1990. The initial sediment sampling results indicated elevated concentrations of polynuclear aromatic hydrocarbons (PAHs), oil and grease, cyanide and heavy metals.

In 1993 and 1994, the WDNR conducted a study of sediment contamination of the Newton Creek system. Murphy and its consultants conducted sampling parallel with the WDNR's 1993 and 1994 sampling efforts, which included collecting sediment samples and water samples from the Newton Creek system. Sediment samples collected by the WDNR from the Newton Creek system in 1993 and 1994 contained elevated concentrations of diesel range organics (DRO), oil and grease, PAHs, and heavy metals. In December 1994, the WDNR completed the sediment investigation report from the Newton Creek system sediment characterization study.

The WDNR developed a separate report in 1995 that integrated information on sediment contamination, sediment toxicity, macroinvertebrate community composition, and sediment thickness collected during the 1993 and 1994 WDNR sediment characterization study. Appendix B includes excerpts of analytical chemistry summary tables from previous project investigation documents. Figure 2 includes the location of the 1993 and 1994 sampling locations.

In August 2002, under contract to the WDNR, SEH completed the Site Investigation Work Plan of Newton Creek and Hog Island Inlet for further investigation activities to support further evaluation of remedial actions.

In April 2003, SEH prepared a Remedial Design Report, Plans and Specifications for the remediation of upstream Segments B-K of Newton Creek. The remediation of these creek segments was completed in September 2003. Visually contaminated sediments (as determined by observations of staining and sheens) were removed. The total amount of visually contaminated sediments and bank soils that were removed was approximately 7,500 tons. Restoration of the creek channel and floodplain areas disturbed by the removal included installation of breaker run and streambed stone, bank stabilization, and revegetation.

2.2 Related Studies

Newton Creek and Hog Island Inlet have been used by the USEPA (e.g., Monson et al. 1995; Ankley et al. 1994; Kosian et al. 1998; West et al. 2001) and WDNR (Patnode) in many studies over the past 10 years to explore aspects and effects of PAH and other petroleum hydrocarbon contaminants. The results of related studies are discussed in further detail in Section 7.

3.0 Field Sampling Activities

This section provides the general summary of the field sampling activities conducted in Segment L of Newton Creek and Hog Island Inlet, including:

- Field screening to delineate visible contamination;
- Floodplain soils and sediment sampling in Newton Creek Segment L;
- Shoreline soils and sediment sampling in Hog Island Inlet;
- Reference shoreline soils and sediment samples collected adjacent to Loons Foot Landing;
- Collection of large-volume (20-gallon) sediment samples in Hog Island Inlet and Loons Foot Landing for toxicity analysis

- Collection of sediment cores in Hog Island Inlet and Loon's Foot Landing for macroinvertebrate population surveys; and
- Surface water sampling in Hog Island Inlet and adjacent to Loons Foot Landing.

The purpose of the investigation was to evaluate shallow site stratigraphy and the extent of subsurface contamination in the Segment L and Hog Island Creek areas. The investigation included comprehensive walking and boating surveys to screen the area of investigation.

The first round of screening sampling took place on August 22, 2002 in and along Segment L. 7 soil and 2 sediment samples were collected from the stream channel and bank areas for visual characterization. Field descriptions of the samples are included in Appendix D, "Field Investigation Data." Screening locations are identified on Figure 3, "2002 Sediment and Soil Screening Locations."

On September 6, 2002 SEH and LSRI collected sediment samples in Hog Island Inlet and the west bay of Loon's Foot Landing for the macroinvertebrate survey analysis and to conduct sediment toxicity tests. Homogenized samples of the sediments (and the control sediment used by LSRI, the toxicity testing laboratory) were also submitted to a laboratory for chemical analysis.

Further sampling of Hog Island Inlet commenced on September 25, 2002 and ended on October 3, 2002. SEH collected 77 core samples of sediment along a 100 foot grid in the inlet and at 23 soil screening locations along the shoreline. Field descriptions of the samples are included in Appendix D and locations are identified on Figure 3. SEH collected 17 sediment samples and 10 soil samples for chemical analysis.

Table 1, "Analytical Methods" provides a summary of the chemical analytical methods performed on the samples. Field activities, decontamination procedures, duplicate sampling, and sample processing were conducted in general accordance with the Quality Assurance Plan included in the SEH Site Investigation Work Plan – Newton Creek and Hog Island Inlet dated August 2002.

3.1 Delineation of Visible Contamination

Prior to beginning subsurface investigation activities, SEH and the WDNR walked the shoreline of Hog Island Inlet and the Newton Creek floodplain to assess existing conditions and select locations for placement of sampling transects.

The comprehensive walking survey included performance of soil probe and core sampling along two transects from Segment L of Newton Creek. Transects were designated numerically from south to north. Soil sampling locations were also designated numerically generally from west to east. The locations of the sample and transect locations are presented on Figure 3.

The comprehensive walking survey of the Hog Island Inlet shoreline included performance of soil probes at 23 shoreline locations. The soil sampling locations are designated numerically from HIS02-1 to HIS02-23, beginning just east of the mouth of Hog Island Inlet, and proceeding in a clockwise direction around the inlet perimeter. The soil sample locations are depicted on Figure 3.

The soil probes were performed using a four-foot long rod mounted on a push-handle. The probe rod was advanced until refusal was encountered or until four feet of soil had been penetrated. The soils retained on the sides of the probe rod were observed and classified. Observations made during soil penetration (e.g., rocks, sand layers, wood) were also noted.

Core samples were collected using a Macrocore® core sampler equipped with disposable acetate liners. The Macrocore® sampler is four feet long and collects a 1.5-inch diameter core. The core barrel was advanced until fat clay soils or refusal was encountered using a slide hammer and steel extension rods. The sampler was then extracted, and the acetate liner was removed, observed, and sealed. Headspace readings using a Flame Ionization Detector (FID) were recorded on each core sample. The field sampling results are recorded in Appendix D.

Sediment conditions were also visibly observed at locations within Hog Island Inlet on a grid pattern. Observations were made from a boat at each location, and included water depth measurement, sediment classification, and contaminant observations. Samples were retained for headspace analysis at some locations. Sediment conditions were assessed at each location using a thin-walled aluminum core sampler capable of collection 1.5-inch diameter cores continuously until refusal is encountered. The core sampler is lowered through the water column to the sediment surface, and then advanced through the sediments using body weight until refusal is encountered. The core sampler was then removed and the sediments extracted for observation. The sediment sampling locations are presented on Figure 2, Figure 3, and Figure 4, "Comparison of Screening to Sampling Locations."

Observations of visually observable contamination in Segment L and the Inlet included:

- The presence of black to grayish-black to grayish colored whole samples or portions of samples and/or the presence of such colored materials adhering to the sampling equipment.
- The presence of black to grayish-black to grayish colored materials in situ observable in deposited sediments on the channel or Inlet bottom, on the bank slopes, as strata in the bank face, or present along the cuts of pits or core holes in the flood plain soils.
- The presence of oil-related sheening on the water surface when the above-described colored sediment or bottom substrates are disturbed through sampling activities or wading in the Inlet or Creek in such substrates.
- The presence of oil-related sheening on the sample or on water associated with the soil or sediment sample when placed in a bowl or pan
- The presence of oil-related sheening on the water surface within any dug pit or core hole associated with the sampling in the floodplain soils.

Secondary methods of observation used to support the determination included:

- Elevated FID readings associated with the samples; or
- The presence of petroleum or hydrocarbon odors associated with the colored substrate materials.

3.2 Sampling Location Documentation

The latitude and longitude of each of the approximately 100 field sampling locations was recorded using a Magellan Meridian Platinum global positioning system (GPS) receiver equipped with wide area augmentation system technology capable of relocating points within a ten foot margin of error. Sample depths were recorded and later tied into survey elevation data.

3.3 Soil and Sediment Sampling for Laboratory Analysis

The field observations compiled during the comprehensive walking survey or sediment screening were utilized to select soil and sediment sample locations for laboratory analysis. The locations selected were intended to represent relatively unimpacted locations, slightly impacted locations, moderately impacted locations, and severely impacted locations (based on the field observations). As shown on

Figure 3 none of the soils screened had either visual or secondary characteristics of contamination.

The soil and sediment samples for laboratory analysis were collected using a decontaminated Macrocore® core sampler or thin-walled aluminum core sampler. The desired sample interval was placed in a zipper locking plastic bag and mixed by hand through the sides of the bag. Portions of the sample were than placed in laboratory clean bottles, preserved as necessary, and chilled to 4 degrees C for transport to the analytical laboratory. The samples were delivered directly to EnChem in Superior, Wisconsin by SEH personnel. Standard chain-of-custody documentation was maintained during sample collection and transportation.

3.4 Surface Water Column Grab Sampling

Two discreet surface water samples (disturbed and undisturbed) were collected from Hog Island Inlet at two separate locations (a total of four samples) shown on Figure 5, "Surface Water Sampling Locations." The sample locations were selected to evaluate areas where contamination was suspected to be present (in vicinity of HI-29 and the mouth of Newton Creek). In addition, two background surface water samples were collected in the reference inlet adjacent to Loons Foot Landing. The samples were intended to measure concentrations of any contaminants in the water column under normal low-flow/undisturbed conditions in Hog Island Inlet and Loons Foot Landing, and the concentrations any contaminants in Hog Island Inlet and Loons Foot Landing when the bottom was being disturbed. The undisturbed sample was collected first at each sampling location by filling sample bottles from the water column at mid-depth without disturbing the bottom. After the undisturbed water sample was collected, the water was entered, and the bottom was disturbed by repeatedly walking across the bottom in waders for approximately two minutes. The sample bottles were filled from the water column at mid-depth in the vicinity where the bottom was being disturbed.

The sample bottles were preserved in the field as necessary and cooled to 4 degrees C. The surface water samples were delivered directly to EnChem's Lab in Superior, Wisconsin by SEH personnel.

3.5 Sediment Sampling for Macroinvertebrates

Sediments for the toxicity test and macroinvertebrate study were collected from three locations in Hog Island Inlet and one reference location (WL-2) near Loons Foot Landing, as shown on Figure 6, "2002 ERA Sampling Locations." The sample collection locations were based on previous study results and the visual survey results. The ERA sample locations were in the vicinity of the 1994 sampling locations and were related to the above relative degrees of contamination: HI-13, HI-27, HI-1, and WL-2.

Five replicate core samples were collected at each site using a piston core sampling device for benthic macroinvertebrate studies. The same sampling device was used previously by the WDNR in 1993 and 1994. The top 15 cm of the core samples were sieved in the field by LSRI personnel using a 250 um-mesh sieve bucket and preserved with a 10% formalin solution. Macroinvertebrates from the sediment samples collected were sorted and identified.

As discussed in Section 7, the results of the analysis were further evaluated for the following metrics: Total Abundance, Abundance and % of Dominant and other taxa (oligochaetes, chironomids, mollusca, and the amphipod *Gammarus fasciatus*), Taxa Richness, Shannon-Wiener diversity values, Biotic Index, Jaccard Coefficient of Community, and the Community Similarity Index.

3.6 Sediment Sampling for Toxicity Analysis

Large-volume (20-gallon) sediment samples were collected by SEH to provide media for toxicity testing. The large-volume sediment samples were collected at the three designated locations discussed above within Hog Island Inlet and at one location in the inlet adjacent to Loons Foot Landing as depicted on Figure 2. These samples were collected from bioactive zone (0 to 15 cm) of sediments using an Eckmann® Dredge. The dredge was repeatedly lowered to the bottom at a location not influenced by previous dredge samples and pushed to a sampling depth of approximately 15 cm , and then closed and extracted. The sediments were placed in clean, five-gallon buckets until 20 gallons of sediment were collected at each location. The samples were then delivered to LSRI's laboratory in Superior, Wisconsin. Standard chain of custody documentation was maintained during sample collection and transport.

Sediments collected for the toxicity test were homogenized at the LSRI laboratory prior to testing. Subsamples of the homogenized sediment were submitted to EnChem laboratory for analysis of DRO, volatile organic compounds (VOCs), heavy metals, total organic carbon (TOC), Acid Volatile Sulfides (AVS) and Simultaneously Extracted Metals (SEM), nitrogen, particle size analysis, and Oil and Grease (O&G). Samples were submitted to Battelle for expanded PAH hydrocarbon analysis.

The homogenized sediment samples were utilized in standard toxicity tests conducted with laboratory populations *of Hyalella azteca, Lumbriculus variegatus*, and *Chironomus tentans*. In parallel tests, the organisms were exposed to ultraviolet (UV) light intensities similar to those at the site. Test results measured survival and growth (due to weight change).

A study of UV light intensities was conducted at the site to determine typical UV intensity at various depths and during various weather conditions. The method used for the field measurement of UV light intensities is found in the LSRI report provided in Subsection E-1 of Appendix E, "Ecological Risk Assessment Documentation."

3.7 Sample Tracking – Chain-of-Custody

Individual labels describing the sample identification, location, sampler's name, date, preservatives, and other relevant information were attached to the sample container. All samples submitted for analyses were tracked using chain-of-custody procedures. Sample bottles were tracked from the laboratory, to the field and back to the analytical laboratory. The chain-of-custody also documents relevant sampling and preservation. Copies of the chains of custody are included with the laboratory results in Appendix F, "Laboratory Analytical Data."

3.8 Laboratory Analysis and Data

The soil and sediment samples were analyzed for concentrations of VOCs, PAHs, TOC, DRO, total cadmium (Cd), total chromium (Cr), total lead (Pb), total mercury (Hg), hexavalent chromium (Cr+6), and/or AVS and SEM. Surface water samples were analyzed for VOCs, PAHs, TOC, Cd, Cr, Pb, Hg, Cr+6, biological oxygen demand (BOD), chemical oxygen demand (COD), O&G, and total suspended solids (TSS). Four sediment and four soil samples were also analyzed for grain size distribution.

Table 1 provides a summary of the various standard analytical methods performed. SEH contracted with EnChem, Inc. to perform the analysis. EnChem is certified by the State of Wisconsin to perform the standard analyses and also performed the chemical analysis for the investigation of Newton Creek Segments B, C and F (SEH, 2000).

Analytical data from the laboratories was submitted to SEH in both electronic and hardcopy form. Data summary tables were constructed from the electronic files to minimize potential for manual data transfer errors. Copies of the laboratory analytical reports are included in Appendix F.

3.9 Decontamination Procedures

Sampling equipment was decontaminated prior to use in the field, or disposable and dedicated to a single sample. Equipment reused in the field at different locations or sampling depths was decontaminated prior to each reuse. Decontamination involved Alconox soap wash and a triple rinse of deionized water.

3.10 Field Quality Assurance Samples

Field QA samples were handled and stored in an identical manner as actual samples. Results of the analysis of the field QA samples are included with the summary report.

Field QA samples included duplicate samples, matrix spike and matrix spike duplicates, and trip blanks. In general, duplicate samples were collected at a frequency of one duplicate per every 10 samples submitted to the analytical laboratory. Trip blanks were analyzed for VOCs, when VOC analyses were being conducted.

3.11 Investigative Waste Management

Excess soil and sediment samples collected during the SI were kept inside the acetate sample tubes or zipper locking bags and stored for additional classification. The samples will be disposed based on review of laboratory analytical results. Sampling residuals (e.g., disposable PPE, excess sample bottles, etc.) were disposed as solid waste.

The analytical chemistry laboratories will dispose of residual sample media in accordance with their waste management plan.

3.12 Property Access Agreements

SEH contacted property owners regarding proposed site activities. Copies of access agreements and/or telephone notification records were provided to the WDNR and field personnel.

4.0 Summary of Investigative Results

The results of the visual delineation of contaminated sediments and floodplains are illustrated on Figure 3. Locations where visual contamination was noted are shown in red. Locations where visual contamination was not noted, but where secondary characteristics (organic odors) were detected are shown in orange. Locations where no visual or secondary characteristics of contamination were detected are shown in green.

Sediment and soil chemical sampling locations are shown in plan view on Figures 2 and 4. Analytical results for sediment, soil, and surface water are summarized in Table 2, "Soil Analytical Results," Table 3, "Sediment Analytical Results," Table 4, "Sediment Expanded Hydrocarbon Analytical Results," and Table 5, "Surface Water Analytical Results." Laboratory analytical reports are provided in Appendix F.

A brief summary of analytical results in the soils, sediments, and surface water is provided below. Further discussion of the results is provided in Section 5.

4.1 Perimeter Wetland Soils

Soil analytical results are summarized in Table 2. As shown on Figure 3 none of the soils screened had either visual or secondary characteristics of contamination.

Ranges of concentrations for samples are shown below:

- TPAHs ranged from non-detect to 4141 µg/kg
- Total VOCs ranged from non-detect to 294 µg/kg
- Hg ranged from 0.021 to 0.45 mg/kg
- Cd ranged from 0.11 to 0.97 mg/kg
- Total Cr ranged from 5.7 to 42 mg/kg
- Cr+6 was not detected
- Pb ranged from 4.7 to 73 mg/kg (with the exception of one very high result of 1100 mg/kg) and
- TOC ranged from 5,200 to 190,000 mg/kg.

4.2 Sediments

Sediment analytical results are summarized in Table 3. TPAH and DRO concentrations are also shown on Figure 7, "2002 TPAH and DRO Map." For the selected sample locations, there were no sediment samples collected that did not exhibit secondary characteristics (odors).

Ranges of concentrations for samples with no visual contamination but with secondary characteristics are shown below:

- TPAHs ranged from non-detect to 4,781 µg/kg
- Total VOCs ranged from non-detect to 58 µg/kg
- Mercury ranged from non-detect to 0.37 mg/kg
- Cadmium ranged from non-detect to 1.8 mg/kg
- Total Chromium ranged from 17 to 61 mg/kg
- Hexavalent chromium was not detected
- Lead ranged from 1.4 to 44 mg/kg and
- TOC ranged from 240 to 160,000 mg/kg.

Ranges of concentrations for samples that appeared to be most visually contaminated are shown below:

- TPAHs ranged from 2607 to 11,280 µg/kg
- Total VOCs ranged from non-detect to 327 µg/kg
- Hg ranged from 0.27 to 0.91 mg/kg
- Cd ranged from 0.81 to 1.2 mg/kg
- Total Cr ranged from 47 to 71 mg/kg

- Cr+6 was not detected
- Pb ranged from 44 to 84 mg/kg and
- TOC ranged from 40,000 to 100,000 mg/kg.

As shown on Table 4, the total concentration of total expanded hydrocarbons (TEH) including PAHs and alkyl substitutes ranged from 11,354 µg/kg for HI-1 to 100,771 µg/kg for HI-13.

4.3 Surface Water

Surface water analytical results are summarized in Table 5.

Ranges of unfiltered concentrations for undisturbed water samples at the two study sites (collected before wading) are shown below:

- Total PAHs (TPAHs) ranged from non-detect to 0.13 µg/l
- VOCs were not detected
- Hg was not detected
- Cd ranged from non-detect to 0.14 µg/l
- Total Cr ranged from 0.94 to 1.5 µg/l
- Cr+6 chromium was not detected
- Pb ranged from 0.77 to 1.1 µg/l
- TOC ranged from 13 to 14 mg/l
- O&G was not detected
- TSS was less than 10 mg/l
- COD ranged from 33 to 43 mg/l
- BOD was less than 6 mg/l

Ranges of unfiltered concentrations for disturbed water samples at the two study sites (collected after wading) are shown below:

- TPAHs ranged from 1.8 to 3.5 µg/l
- VOCs were not detected
- Hg ranged from 0.06 to 0.49 µg/l
- Cd ranged from 0.19 to 1.1 µg/l
- Total Cr ranged from 4.1 to 52 µg/l
- Cr+6 was not detected
- Pb ranged from 21 to 87 µg/l
- TOC was 15 mg/l
- O&G ranged from non detect to 3.1 mg/l
- TSS ranged from non detect to 640 mg/l
- COD ranged from 35 to 45 mg/l
- BOD was less than 6 mg/l

Disturbance of the sediments at the study sites in Hog Island Inlet resulted in the suspension of PAH contaminants at concentrations an order of magnitude higher than in the undisturbed water column. This effect was not observed at the reference site (WL-2).

4.4 Biological Studies

The biological studies conducted by LSRI were completed successfully on the surface sediments. Results of the toxicity tests and macroinvertebrate enumeration taxonomy survey conducted on the surface sediments are included in Appendix E-1 and E-3. The results of these studies are discussed in further detail in Section 7.

5.0 Discussion of Results

5.1 Chemical Analytical Results

5.1.1 Soils

Examination of Figure 7 reveals that soil PAH concentrations were highest at perimeter wetland/shoreline locations (HIS02-2, HIS02-18, and HIS02-21) adjacent to the areas of previously identified sediment contamination.

As indicated on Table 2, in some locations soil PAH concentrations exceeded interim guideline RCLs based on the non-industrial direct contact pathway (WDNR, 1997). However, as described in a subsequent section, the soil PAHs did not appear to pose a site-specific human health risk above the 1×10^{-5} criteria.

A high lead concentration (1,100 mg/kg) was detected at HIS02-13. The high concentration may be due to the presence of lead shot or some other lead-containing artifact although this was not detected or noted at the time of field sampling. The lead is not believed to be associated with coal because the lead concentration is much higher than would be associated with coal, and the other metals are not similarly elevated. Lead content in coal from the western U.S. is approximately 5 mg/kg and lead in coal ash is 0.40 to 250 mg/kg (Janisch, 1992; Liberati, 1985).

5.1.2 Sediments

Figure 3 illustrates the areal extent of visually contaminated sediments in Hog Island Inlet. Field notes provided in Appendix D indicates the vertical extent of visual contamination is generally 2 to 3 feet deep, but may extend as deep as 6 feet in some areas.

As shown on Table 3, sediment samples with no visually identified contamination but with secondary signs of contamination exhibited a significantly lower maximum concentration in the range of concentrations for all contaminants when compared to samples with visually identified contamination.

Table 6, "Comparison of 2002 Results to 1993 and 1994 Results" provides a comparison of analytical results for sampling conducted at HI-1, HI-13, and HI-27 between the current and past studies.

TPAH, VOC and metals contaminant concentrations identified within the wetland perimeter soils and sediments are of the same magnitude and within the same range as previously identified in the 1995 Newton Creek System Site Characterization (WDNR, 1995a). Summary tables from the previous reports are provided in Appendix B.

DRO concentrations appear to be less in the current round of sampling when compared to 1993 and 1994 results. Decreases in DRO concentrations may be due to differences in laboratory methodology for DRO analysis. The Wisconsin Modified DRO method was revised and standardized in September 1995 (WDNR, 1995b), after the 1993 and 1994 DRO samples were analyzed. The integration method currently utilized may result in lower results than the method utilized 10 years ago. Alternatively, decreases in DRO concentrations may be due to sampling location heterogeneity or biodegradation of non-PAH hydrocarbons.

5.1.3 Surface Water

Contaminant concentrations in the undisturbed water samples were significantly lower than in the "disturbed" water samples collected after wading in the sediment. The differences between undisturbed and disturbed concentrations of contaminants is relatively large at the study sites (HI02-29 and NC-Mouth) compared to the results from the reference site (WL-2). Surface water samples were not filtered and it is likely that much of the contamination observed in the disturbed water samples were associated with suspended solids containing adsorbed contaminants.

5.2 Duplicate Samples

5.2.1 Field Duplicates

Comparison of the undisturbed duplicate water samples exhibited good correlation for all chemical analyses (Table 5).

Comparison of the duplicate wetland soil sample collected at HIS 02 (0-1 ft) indicates localized variation may exist at the sample collection point as relatively large differences (>50%) were noted for many of the chemical analyses (PAHs and metals) as shown on Table 2.

Comparison of the duplicate sediment sample collected at HI-77 (0-0.5 ft) on October 2, 2002 indicated good correlation for most of the chemical analyses. Comparison of DRO and some PAH and VOC concentrations exhibited greater than 50% difference as shown on Table 3.

Comparison of the duplicate sediment sample collected at HI-27 (0-0.5 ft) on September 10, 2002 indicated good correlation for most of the chemical analyses. Comparison of the DRO exhibited greater than 50% difference.

5.2.2 PAH Analysis Methods

Comparison of sediment samples collected at the same general locations of HI-13, HI-27, HI-1, and WL-2 in September 2002 and October 2002 exhibited notable differences for PAH concentrations. This may be due to variability in the sample locations and heterogeneity in contaminant distribution, or due to differences in the lab methods between EnChem and Battelle.

EnChem utilized sample preparation method SW846 3545 for pressurized fluid extraction. Samples were analyzed via EPA method 8270C.

Battelle utilized sample preparation method SW846 3550 for extraction via sonification. Samples were further processed through an alumina cleanup column following EPA 3611B to remove polar and biogenic contaminants and treated with activated copper to remove sulfur, a major interferant found in anoxic sediments. Samples were analyzed via a modified version of EPA 8270 in which the mass spectrometer was operated in the selected ion monitoring mode to improve specificity and detection limits for target PAH compounds. The method utilized by Battelle likely provides more accurate results due to the cleanup methods employed, which would reduce interference from other compounds (such as sulphur).

6.0 Human Health Risk

6.1 Background

This section presents a Human Health Risk Assessment (HHRA) for Hog Island Inlet and the inlet mouth from the Newton Creek system to Superior Bay. This HHRA is meant to supplement the human health risk evaluation conducted by the WDNR and presented in the document titled "Newton Creek System Sediment Contamination Site Characterization Report" dated December 1, 1995 (WDNR 1995a).

The risk assessment conducted by WDNR in 1995 focused on risks present in the entire Newton Creek system including the Newton Creek Impoundment, Newton Creek itself and Hog Island Inlet. It was based on data collected by the WDNR in 1993 and 1994. The HHRA presented here is limited to current data collected from Hog Island Inlet only. A risk assessment was conducted by SEH on Newton Creek Segments B and C in September 2000.

The HHRA was performed to evaluate the current and future potential adverse health effects caused by hazardous substance releases from the

site in the absence of any actions to control or mitigate these releases (USEPA, 1989). This HHRA is conducted in accordance with USEPA's Risk Assessment Guidance for Superfund: Volume I (USEPA, 1989) and Vol. II (USEPA, 1991), also known as RAGS. Calculation of potential risks associated with the site are performed by the SADA (Spatial Analysis and Decision Assistance) Model, version 3.0, developed by the University of Tennessee, Knoxville in collaboration with Oak Ridge National Laboratory (ORNL). The development of SADA is supported by the US Environmental Protection Agency, the US Nuclear Regulatory Commission, and the US Department of Energy.

6.2 Overview

6.2.1 Risk Assessment

The risk assessment process includes four components: data collection and evaluation; exposure assessment; toxicity assessment; and risk characterization. Each step is described briefly below.

Data Collection and Evaluation – involves the gathering and analyzing of relevant site data. Sampling results from the various environmental media are reviewed to identify the compounds detected above background concentrations. Chemicals detected above background concentrations are termed chemicals of potential concern (COPC). COPCs are then evaluated quantitatively and qualitatively to determine the human health risk associated with the site.

Exposure Evaluation – involves the evaluation of various pathways, magnitude, frequency, and duration of potential exposure to the identified COPCs. Reasonable maximum estimates of exposure are reviewed for both current and future land uses. This component involves analyzing contaminant releases, identifying exposed populations, identifying potential pathways of exposure, and uptake concentrations. Concentrations in the environmental media to which populations at risk may be exposed are based on sampling and monitoring data or estimated by fate and transport model algorithms.

Toxicity Assessment – considers available evidence on the potential for contaminants to cause adverse health effects in exposed individuals. Toxicity assessments consist of two steps: 1) hazard identification and 2) dose-response evaluation. Hazard identification determines whether exposure to an agent can cause an increase in the incidence of an adverse health effect. Dose-response quantitatively evaluates the toxicity information and characterizes the relationship between the dose of the contaminant and the incidence of adverse health effects. From these two steps, toxicity values are developed that can be used to estimate the likelihood for adverse effects in a given population.

Risk Characterization – summarizes the exposure and toxicity assessment outputs to characterize the risk both quantitatively and qualitatively. Non-carcinogenic effects are presented as a ratio between projected intake concentrations and toxicity values or reference doses. Carcinogenic effects are presented as a probability that an individual will develop cancer in excess of that expected over a lifetime of exposure. Estimates of the uncertainties contained in the assessment are also presented.

6.2.2 SADA

The current version of SADA contains a full HHRA module and associated databases. The risk models follow RAGS, as described in this document, and can be customized to fit site specific exposure conditions. SADA provides an HHRA module to calculate the risk of adverse health impacts on a population exposed to toxic chemicals found in groundwater, surface water, soil, and sediment. It also calculates risk-based screening values to quickly identify contaminants of concern. In SADA, five land use scenarios can be considered: residential, recreational, industrial, excavation, and agricultural. Exposure routes that are available are ingestion, inhalation, dermal contact, and food chain intake.

6.3 Land Use Conditions

A residential area is located to the southwest of E. 2nd Street, approximately 300 feet southwest of the embayment. Hog Island Inlet is readily accessed by the public and is often used for recreational activities such as walking, wading or swimming. For this risk assessment, current and future use of the site is recreational for both adolescents and adults. Children (under six years of age) typically do not frequent the site. Hog Island and Hog Island Inlet are shown on Figures 1 and 2.

Drinking water in the vicinity of the site is provided by the City of Superior. The City of Superior obtains approximately 95% of its drinking water from a well field located on Minnesota Point, approximately 3,500 feet northeast of the site. There are no sources of drinking water from the shallow groundwater table at the site. It is assumed that no drinking water supply wells in the shallow groundwater table will be installed in the vicinity of the site in the future and the City of Superior will continue to provide drinking water to the area.

6.4 Identification of Chemicals of Concern

In this process, the full list of chemical parameters analyzed are screened to remove those that are not above background concentrations or do not contribute significantly to overall risk at the site.

6.4.1 Data Evaluation

Sampling at Hog Island and Hog Island Inlet was conducted during October and November 2002 in accordance with the Newton Creek and Hog Island Inlet Site Investigation Work Plan (SEH 2002) dated August 2002. The Work Plan has been described in Section 1.3 of this document. Chemical parameters analyzed included PAHs, VOCs, and select metals (Cd, Cr, Cr+6, Hg, Pb). Laboratory analytical results from the Segment L/Hog Island Inlet are summarized in Tables 2, 3, 4, and 5. Copies of the laboratory reports can be found in Appendix F. Analytical sample locations can be found on Figures 2 and 5.

Upon completion of site sampling, the following steps were taken to organize and evaluate the data:

Data were sorted by media contributing to a complete exposure pathway: surface soil (0-1 ft. depth), surface sediments (0-0.5 ft. depth), and unfiltered disturbed surface water.

Data were evaluated with respect to qualifiers and codes. As a result of this evaluation, several flags on the data were noted, including: "Q" - the analyte is detected between than the limit of quantitation and the limit of detection and there is uncertainty in calculation of the results within this range. All data was usable as reported with qualifiers noted. No "R" qualifiers or disqualified data were identified.

Analytical levels of detection for soil samples were evaluated to determine if appropriate to ascertain compliance with ch. NR 720, Wis. Admin. Code generic residual contaminant levels (RCLs). All detection limits were sufficient for evaluation of ch. NR 720, Wis. Admin. Code RCLs. Where RCL values were unavailable, analytical levels of detection for sediment, soil, and surface water were screened against USEPA Region 3 Risk-Based Concentrations for residential soil and drinking water as a conservative measure. No analytical results were eliminated as a result of this screening procedure.

In the case of replicate samples, the highest detected value was used and the others eliminated as a conservative measure.

Chemicals that were analyzed, but not detected, were assumed to be present at one half the detection limit. Chemicals that had an "assumed" value greater than an actual detected concentration within a media group were removed from the data set.

Chemicals that are detected infrequently (less than 5% detection) in a media group should be eliminated from evaluation. This screening requires a minimum of 20 samples within a group. Since all media groupings had fewer than 20 samples, all analyzed chemicals were retained for risk evaluation.

Because naphthalene is included as a parameter in both the VOC and PAH range, in order to avoid redundancy and as a conservative measure, only the highest naphthalene concentration was retained in each data set.

Background samples were removed from the data set prior to import into SADA.

6.4.2 Media Types

The risk assessment presented in this section was conducted for Hog Island Inlet only. Hog Island Inlet is associated with the three media types contributing to a complete exposure pathway: soil, sediment, and unfiltered surface water. Sample media and locations associated with this risk assessment are summarized in Table 7, "Human Health Risk Assessment Media Types and Locations."

6.4.3 Background Samples

Comparison of site concentrations with background concentrations is useful in identifying non-site-related chemicals or background concentrations found at or near the site. Background levels may be naturally occurring or due to anthropogenic sources but not site-related. Background samples must be collected in areas that have the same basic characteristics as the medium of concern at the site, but could not have received contamination from the site. In accordance with RAGS, comparison of site concentrations with naturally occurring levels is applicable only to inorganic chemicals. The majority of organic chemicals are not considered to be naturally occurring. Therefore, all organic chemicals analyzed were retained as COPCs for risk evaluation.

Background samples for all three media types were collected from the location designated as WL-2 or WL-2A. Low concentrations of select PAHs were detected in background samples, particularly surface soil samples. The presence of organic chemicals in background samples may indicate the area has received low level inputs from ubiquitous urban sources such as nearby highway, marina, and former commercial dock.

A compliment of 25 metals was analyzed in the November 1999 sediment sampling event to determine the presence or absence of various select metals in terms of human health exposure. At that time, no unusual concentrations were noted. As a result of that sampling event, it was decided by WDNR that metal testing for this investigation phase would be limited to cadmium, chromium, mercury, and lead.

During the current sampling event, 14 select metals were analyzed in the homogenized sediment samples collected for ecological risk assessment. The homogenized samples were not used in the HHRA. It is noted however, that arsenic exceeds the ch. NR 720 RCL for both industrial and residential settings in the homogenized sediment samples. In addition, beryllium and iron exceed the USEPA Region 3 Risk-Based Concentrations for soils in a residential setting that was used as a screening tool. Since arsenic, beryllium, and iron were not analyzed in the laboratory samples used in the HHRA, the unknown chemical concentrations of these parameters present an uncertainty factor to the risk calculations. Uncertainty associated with unknown parameter concentrations will be discussed in the uncertainty section.

It should be further noted that the concentrations of arsenic, beryllium, and iron in sediments generally represent background conditions even without ubiquitous anthropogenic input. As such, they may represent a degree of uncontrollable exposure risk that cannot practically be addressed through any type of remediation.

The background screening consisted of a comparison of local background concentrations to site-specific mean and maximum concentrations. If the comparisons were not in agreement, further comparison was made to typical Wisconsin state soil ranges for inorganic parameters (WDNR, 1980) and USGS background inorganic concentrations in soils. A published background reference concentration was not readily available for surface water. In this case, only the comparison between local background and site-specific mean and maximum concentrations was conducted.

Site inorganic parameters (with the exception of total Cr in surface soil) were found to be above background concentrations. Therefore, none of the inorganic parameters were eliminated as a COPC. Total chromium in surface soils was found to be at background concentrations. As a conservative measure, total Cr was retained as a COPC for risk evaluation. A summary of the comparison of site inorganic concentrations to background inorganic concentrations can be found in Appendix G, "Human Health Risk Assessment," sub-appendix G-1, "COPC Screening Tables," Tables G-1-1 through G-1-3.

The data collection, evaluation, and screening processes described above were used to identify chemicals of potential concern at the site. A summary of COPCs, listed by media type can be found in Table 8, "Human Health Risk Assessment Chemicals of Potential Concern." A summary of the various media data and statistics associated with the Hog Island Inlet risk assessment can be found in Appendix G-2, "HHRA Statistics," Tables G-2-1 through - G-2-3.

6.5 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the contaminants of concern that are present or migrating from the site. Exposure is defined in RAGS as the contact of an organism with a chemical or physical agent. The magnitude of exposure is determined by measuring or estimating the amount of an agent available for bodily intake during a specified time period (USEPA 1989).

6.5.1 Potentially Exposed Populations and Pathways

The site is adjacent to a residential area and is readily accessible by the public. There is no access control to the area of concern. The area is visited regularly by both adolescents and adults on a recreational basis. Activities include walking pets near the inlet and Hog Island perimeter areas, wading, swimming, and fishing in the inlet water and playing in adjacent fields and tall grass areas to SW of RR tracks, at Lakehead Pier and on Hog Island itself.

Under current and future conditions, recreational land use is considered for both adolescents and adults with media of concern being surface soils (0-1 ft. depth), surface sediments (0-0.5 ft. depth), and unfiltered disturbed surface water. Exposure routes considered are incidental ingestion and dermal contact of all three media, inhalation of volatiles and particulates, and fish consumption. A summary of the exposure pathways is found on Table 9, "Human Health Potential Exposure Pathways."

6.5.2 Quantification of Exposure

The magnitude, frequency, and duration of exposure are quantified for each exposure pathway and identified population potentially at risk in this process. This process involves two steps: 1) estimate the concentration of chemicals to which the current and future populations may be exposed and 2) calculate the chemical specific intakes for each exposure route.

6.5.3 Intake Concentrations

Exposure estimates presented in this risk assessment are based on a reasonable maximum exposure (RME). The RME is the highest exposure that is reasonably expected to occur at a site. The intake concentration used by the SADA model is an estimate of the arithmetic mean concentration for a contaminant based on the set of sample results. Typically in data sets greater than 10 samples, the 95% upper confidence limit (UCL) of the arithmetic mean is used because of the uncertainty associated with estimation of the true mean. Because the data sets for all three media in this risk assessment are less than 10 samples, the maximum detected concentration was used to estimate

exposure concentration. The statistics associated with the media types are found in Appendix G-2.

6.5.4 Chemical Intakes for Specific Pathways

Exposure is defined as the contact of an organism with a chemical or physical agent. Exposure normalized for time and body weight is termed "intake" and is expressed in units of milligrams of chemical taken in per kilogram of body weight per day, averaged over a specified exposure period. Chronic daily intakes are calculated for each COPC that have been analyzed at the various pathways of concern. The following formula represents a generic equation for calculating chemical intakes followed by definitions of the input parameters:

$$I = \frac{C * CR * EF * ED}{BW * AT}$$

Where:

I = Intake; the amount of chemical at the exchange boundary (mg/kg-day)

C = Chemical Concentration; the average concentration contacted over the exposure period (mg/l) or (mg/kg)

CR = Contact Rate; the amount of contaminated medium contacted per unit time or event (l/day) or (mg/day)

EF = Exposure Frequency; describes how often exposure occurs (days/year)

ED = Exposure Duration; describes how long exposure occurs (years)

BW = Body Weight; the average body weight over the exposure period (kg)

AT = Averaging Time; period over which exposure is averaged (days)

Source: RAGS Part A

The above generic intake equation is modified for the various exposure pathways to reflect pathway-specific parameters. The intakes calculated in this step are expressed as the amount of chemical at the exchange boundary (i.e., skin, lungs, gut) and available for absorption. The various land use scenario assumptions that are utilized in the risk assessment by the SADA model along with the source of the values are located in Appendix G-3, "Assessment Scenario Assumptions."

In choosing input parameters, first consideration was given to values specified in Wisconsin Administrative Code. When specific parameters are not listed in code, site specific values that reflect scenario conditions were used. Where no site-specific value was applicable, USEPA recommended values were used. It is believed that these values represent conservative estimates for the parameters noted.

Specific equations used by SADA to calculate intake of the three media types and for the pathways selected for this site can be found in Appendix G-4, "Intake Equations."

6.6 Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for a contaminant to cause adverse health effects in exposed populations. An estimate is then made of the relationship between the extent of exposure and the likelihood and severity of adverse effects. USEPA has performed the toxicity assessment step for many chemicals and has made toxicity information and values available. The assessment performed by USEPA has undergone extensive peer review and will be used in this assessment.

The Toxicological database used by SADA in this risk assessment is taken from ORNL's Risk Assessment Information System, version 3.3, dated August 13, 2002 (RAIS, 2002). This database is maintained regularly, and recent versions of the database can be downloaded periodically in a SADA compatible format. The toxicity values were compiled from information found in USEPA's Integrated Risk Information System (IRIS), USEPA's Health Effects Assessment Summary (HEAST), derived from values found in these sources, or provided after contacting USEPA.

If a toxicity value was not readily available, then the chemical could not be included on a quantitative basis and is discussed in the uncertainty section and in the qualitative risk discussion (Section 7.8). It should be noted that the absence of a toxicity value does not imply that the chemical possesses no adverse exposure related health response. It may simply mean that sufficient data have not been collected and evaluated to date to make a conclusive toxicity characterization judgement for that chemical or that time elements may have led to certain chemicals being evaluated before others. A summary of the toxicological information used in this HHRA can be found in Appendix G-5, "Toxicity Information."

6.7 Risk Characterization

In the risk characterization process, the information gathered in the exposure evaluation and toxicity assessment phases are integrated into quantitative estimates of risk. To characterize potential non-carcinogenic effects, comparisons are made between projected intakes of substances and toxicity values (RfDs). To characterize potential carcinogenic effects, probabilities that an individual will develop cancer over a lifetime of exposure are estimated from projected intakes and toxicity information slope factors (SFs).

6.7.1 Quantifying Risk

Non-Carcinogenic Hazard

The potential for the manifestation of non-carcinogenic effects is evaluated by comparing an exposure over a specified time period (intake) with a reference dose (RfD). This ratio of exposure to toxicity values is termed hazard quotient (HQ) and is calculated as follows:

$$HQ = \frac{I}{RfD}$$

Where:

HQ = Hazard Quotient

I = Chronic daily intake (mg/kg-day)

RfD = Reference Dose (mg/kg-day)

To express the overall potential for non-carcinogenic effects posed by exposure to more than one chemical, the USEPA has developed an approach that assumes simultaneous exposures to multiple chemicals is additive and could results in an adverse health effect assuming the same mechanism of action, or target organ.

For multiple chemical exposures, the Hazard Index (HI), which is the sum of applicable HQs, can exceed one, predicting adverse health effects, even if no individual intake value is greater than its' respective reference dose. SADA combines the exposure evaluation step of calculating daily chronic intakes and applying the RfDs to arrive at a quantification of the HQ and in turn HI.

If it is likely that the same individual would consistently encounter the exposures of more than one pathway, then the estimated risks may be additive. SADA then combines the risk from the selected exposure routes to arrive at a total HI or non-carcinogenic risk for a specified land use and medium.

SADA spreadsheets containing the HQs and total HIs can be found in Appendices G-6, "Hog Island Inlet Risk." Risks associated with Hog Island Inlet are found on Tables G-6-1 through G-6-3.

6.7.2 Carcinogenic Risk

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the chemical. The SF converts daily estimated intakes averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. The low dose-response relationship is assumed to be linear and SF assumed to be constant. The linear low dose cancer equation to predict excess lifetime cancer risk from exposure to a chemical is:

$$Risk = I * SF$$

Where:

Risk	=	Incremental probability of an individual developing cancer (unitless)
I	=	Intake;chronic daily intake averaged over a lifetime of 70 years (mg/kg-day)
SF	=	Slope Factor (kg-day/mg)

Exposure to site contaminants usually involves exposure to multiple chemicals producing carcinogenic effects in each exposure route. In order to approximate the combined risks associated with this multiple chemical exposure, it is assumed that the individual chemical risks are additive and that each chemical acts independently of the others.

The exposure evaluation step of calculating daily chronic intakes and applying the SFs to arrive at a quantification of risk has been combined in SADA. In addition, SADA then combines the risk from the selected exposure routes to arrive at a total carcinogenic risk for a land use and medium.

SADA spreadsheets containing the total carcinogenic risks can be found in Appendices G-6, "Hog Island Inlet Risk." Risks associated with Hog Island Inlet are found on Tables G-6-1 through G-6-3.

6.7.3 Risk Uncertainty

Risk measures in a risk assessment are not fully probabilistic estimates of risk, but conditional estimates based on a considerable number of assumptions about exposure and toxicity. Areas of uncertainty for the risk assessment generally include land use assumptions, environmental sampling and analyses, exposure point concentrations, toxicological data and exposure intake parameter selection. The major uncertainties associated with this risk assessment are presented below and summarized in Table 10, "Summary of Human Health Risk Assessment Uncertainties."

Current and future land use was determined through discussion with the WDNR and observation. There are no land use restrictions limiting activities on the site. Zoning and land use policy could alter assumptions made in the future, thus changing exposure parameters.

An assumption was made that the environmental concentration of contaminants is at steady-state conditions at the sampling points. No consideration is given to attenuation or degradation of compounds in the environmental media. Use of steady-state conditions is health-conservative and results in a probable overestimation of calculated risk. Future scenarios were evaluated using present contaminant concentrations. This assumes a constant non-diminishing or increasing source which can either over- or under-estimate risk.

Calculation of risk due to fish ingestion is based on fish tissue concentrations derived from the concentration of contaminants in surface water. It was assumed that the majority of fish consumed are not bottom feeders and are primarily exposed to surface water concentrations that are undisturbed. Therefore, undisturbed surface water concentrations were used in the calculation of risk. Bottom feeding fish such as bullheads disturb the surface layer of sediments and are potentially exposed regularly to higher concentrations of contaminants. The calculation of risk due to fish ingestion may be under-estimated depending on the species of fish consumed.

It has also been assumed that the site has been accurately characterized. Chemical analysis for metals for this risk assessment was specified by the WDNR and limited to cadmium, chromium, mercury, and lead. If chemical analysis does not include parameters that may have contaminated the site, risk will not be properly determined. Based on the chemical analysis results of the homogenized sediment samples for ecological risk assessment (not used in this HHRA), there is a potential of additional metal contaminants. An under-estimation of risk could result from improper site characterization and unknown contaminant concentrations.

Toxicity information for many chemicals can be limited. Therefore, varying degrees of uncertainty associated with toxicity data exist. Sources of uncertainty associated with toxicity information includes:

- Extrapolation of dose-response data from effects observed at high doses to predict adverse health effects occurring at low-level exposure.
- Extrapolating dose-response information from short-term studies to predict effects of long-term studies and vice-versa.
- Extrapolating dose-response information from animal studies to predict adverse health response in humans.
- Extrapolating the dose-response information from homogeneous animal or human populations to predict the effects in the general, heterogeneous population.

In addition, to the above source of uncertainty, chemical contaminants are present for which toxicity values are not readily available. These chemicals cannot, therefore, be included in a quantitative risk assessment even though risk may be present. Chemicals not included because of lack of toxicity information or because they were not included as part of the analysis package may underestimate risk.

6.8 Qualitative Risk Discussion

As stated above, a number of chemicals identified as COPCs at the site do not have toxicity values developed for them and therefore, a quantitative risk analysis cannot be conducted on these chemicals. Chemicals that will be addressed qualitatively are as follows:

Lead

Exposure concentrations to dissolved lead in the surface water of Hog Island Inlet range from 0.68 µg/l when sediments have not been disturbed to 87 µg/l when sediments are disturbed. Exposure concentrations to surface sediments range from 1.4 mg/kg to 70 mg/kg. Exposure concentrations to surface soils range from 4.7 mg/kg to 1100 mg/kg.

Soil lead levels of 400 mg/kg or less typically do not require further action based on "Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities" (USEPA 1994). However, the s. NR 720.11, Wis. Admin. Code RCL for lead at non-industrial sites is 50 mg/kg.

Both the soil and drinking water standards are risk-based standards. The RCL for lead has been exceeded sporadically at the site in both surface soils and surface sediments.

Though the water in Hog Island Inlet is not a source of drinking water, it is associated with Superior Bay, which is classified as supporting a cold water fish community and public water supply usage. Hog Island Inlet and Superior Bay are classified for fish and other aquatic life uses with the subcategory of Great Lakes communities.

For this risk assessment, the Inlet is also considered to be classified ~~as~~ on a cold water community/public water supply basis. Application of surface water criteria in Wisconsin is based on unfiltered water samples. Incidental ingestion will potentially occur during recreational activities at the site. Comparison to the surface water standards indicates that the standards are exceeded in the water samples collected when sediments have been disturbed, as may occur during swimming and wading.

The toxic effects from lead exposure form a continuum from clinical or overt effects to subtle or biochemical effects. The most sensitive effects in infants and children involve the nervous systems and developmental effects. For adults, the concerns are peripheral neuropathy and/or chronic neuropathy. The most sensitive effect for adults in the general population may be hypertension. Anemia due to lead exposure is uncommon without other detectable effects or other synergistic factors. Other target organs are the gastrointestinal and reproductive systems (Casarett and Doull, 1991). Adults who drink

water contaminated with lead over many years could develop kidney problems.

1-Methylnaphthalene & 2-Methylnaphthalene

1-methylnaphthalene or 2-methylnaphthalene is similar to naphthalene in structure, is found under similar circumstances and is believed to act in much the same way as naphthalene. These compounds can enter the body in the air that is breathed, by drinking water that contains these chemicals or absorption through the skin. Once in the body, small amounts will dissolve in the blood. They are then carried to the liver and other organs. These chemicals are passed from the body mainly through the urine. Breakdown products are also found in the stool.

Though less toxic than naphthalene, the methylnaphthalenes act somewhat like naphthalene in the body. Naphthalene may damage or destroy some red blood cells resulting in anemia. Naphthalene can also move to an unborn fetus causing anemia in the fetus as well. Naphthalene can also appear in breast milk where it can be transferred to a nursing child. Naphthalene as well as the methylnaphthylenes also appear to be able to damage the lung lining when breathed. There currently are no regulations or advisories for protection of human health (ATSDR, 1995).

Acenaphthylene, Phenanthrene, and Benzo(g,h,i)perylene

Acenaphthylene, phenanthrene, and benzo(g,h,i)perylene are part of the PAH group. Although health effects of individual PAHs are not exactly alike, they exhibit harmful effects that are representative of PAHs in general. PAHs are typically found together as a mixture with other PAHs. PAHs can enter the body through the lungs, by ingestion of food or water, and through skin absorption. Once in the body, PAHs can spread and target fat tissues. Target organs include kidneys, liver, and fat. Smaller amounts are stored in the spleen, adrenal glands, and ovaries. PAHs exit the body generally within a few days through the urine and feces. These three chemicals have not been classified as to human carcinogenicity, although individuals exposed to mixtures that contain PAHs and other compounds have developed cancer. Studies in animals have also shown that PAHs can cause harmful effects on skin, body fluids, and the immune system after both acute and chronic exposure.

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended occupational exposure limit, time-weighted average for coal tar products of 0.1 mg/m^3 of air for a 10-hour workday, within a 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends an occupational exposure limit for coal tar products of 0.2 mg/m^3 for an 8-hour workday, within a 40-hour workweek. The Occupational Safety and Health Administration (OSHA) has established a legally

enforceable limit of 0.2 mg/m^3 averaged over an 8-hour exposure period. (ATSDR, 1995)

6.9 HHRA Summary

Table 11, "Human Health Risk/Hazard Indices Summary - Adults" and Table 12, "Human Health Risk/Hazard Indices Summary - Adolescents" contains a summary of predicted risk for the potential land use exposure scenarios at Hog Island Inlet. Risk is predicted separately for adolescents and adults. The risk presented in this risk assessment is based on RME estimates. In accordance with guidance presented in RAGS, actions as a result of risk assessment should be based on RME estimates. The intent of the RME estimate is to provide a conservative exposure case that is still within the range of possible exposures.

6.9.1 Potential Cumulative Risk

The sum of the current and future exposure pathways for recreational use of Hog Island Inlet by adolescents shows an excess cancer risk of 3×10^{-5} and a non-cancer hazard index of 0.11. The sum of the current and future exposure pathways for recreational usage of Hog Island Inlet by adults shows an excess cancer risk of 3×10^{-5} and a non-cancer hazard index of 0.058.

Cumulative risk defined in ch. NR 720 Wisconsin Administrative Code specifies that the excess cancer risk may not exceed 1×10^{-5} and the non-carcinogenic hazard index may not exceed 1. Tables 11 and 12 indicate that the non-carcinogenic hazards due to recreational use by both adults and adolescents are within acceptable limits at Hog Island Inlet. Carcinogenic risks to both adults and adolescents are slightly elevated above acceptable limits.

6.9.2 Recreational Risk Pathways

Swimming

Cumulative carcinogenic risk to adults and adolescents as the result of swimming in the Hog Island Inlet water is 3×10^{-5}, and 2×10^{-5} respectively. The cumulative non-carcinogenic hazard index for adults is 0.022 and 0.053 for adolescents. The non-carcinogenic hazard indices are acceptable based on ch. NR 720, Wis. Admin. Code. Carcinogenic risk is slightly elevated for both adults and adolescents.

Wading

Cumulative carcinogenic risk to adults as the result of wading in the Hog Island Inlet water is 8×10^{-6} and 7×10^{-6} for adolescents. The cumulative non-carcinogenic hazard index for adults is 0.0083 and 0.019 for adolescents. Both carcinogenic risk and hazard indices are acceptable based on ch. NR 720, Wis. Admin. Code.

Shore Use

Cumulative carcinogenic risk to adults as the result of near shore use at Hog Island Inlet is 2×10^{-7} and 3×10^{-7} for adolescents. The cumulative non-carcinogenic hazard index for adults is 0.0042 and 0.0099 for adolescents. Both carcinogenic risk and hazard indices are acceptable based on ch. NR 720, Wis. Admin. Code.

Fish Consumption

Carcinogenic risk to adults as the result of ingestion of fish that reside in Hog Island Inlet is 3×10^{-9} and 2×10^{-9} for adolescents. Non-carcinogenic hazard index for adults is 0.023 and 0.036 for adolescents. Both carcinogenic risk and hazard indices are acceptable based on ch. NR 720 Wis. Admin. Code.

It is assumed that fish ingested are not bottom feeders and do not regularly disturb the surface sediments. Bottom-feeding fish routinely forage in the sediments and may be exposed to increased concentrations of contaminants (similar to those exhibited for disturbed water samples). If bottom-feeding fish, such as bullheads, were ingested at the same rate as non-bottom feeders, carcinogenic risk would be sharply increased for both adults and adolescents to 7×10^{-3} and 4×10^{-3}, respectively (based on fish exposure to disturbed water samples). Non-carcinogenic hazard indices would also be increased but would still be less than one and therefore, within acceptable levels.

6.9.3 Chemicals of Concern

The SADA model screens data against an acceptable risk level, giving an indication of the chemicals that contribute significantly to the risks present in a given scenario and for a given media. SADA screens individual chemicals against a target cancer risk of 1×10^{-6} and a target non-carcinogenic health index of 1. Scenario risk screens are presented in Appendix G-7, "Risk Screen" on Tables G-7-1 through G-7-2.

The principal chemical contributors to carcinogenic risk in the surface water due to dermal absorption at Hog Island Inlet are:

- benzo(a)anthracene,
- benzo(a)pyrene, and
- benzo(b)fluoranthene.

These chemicals may present a risk while swimming or wading. No excess risk was noted from chemicals that produce non-carcinogenic effects. Nor was excess risk indicated with near shore use.

6.9.4 Comparison to Historical Risk Assessment Results

Comparison between the current risk assessment and the assessment performed by the WDNR in 1995 indicates similar results. Non-carcinogenic hazards were shown to be below the level of concern in both 1995 and the current assessment.

Total estimated excess lifetime cancer risk from exposure to Hog Island Inlet are also relatively comparable. Excess lifetime cancer risk calculated in 1995 was 3.2E-06. Current carcinogenic risk is estimated at 3×10^{-5} . Current estimated carcinogenic risk is slightly elevated above the acceptable ch. NR 720, Wis. Admin. Code standard of 1×10^{-5}.

6.9.5 Clean-up Considerations

The SADA program calculated individual chemical screening goal concentrations corresponding to a specified risk level for chemicals of concern. The target carcinogenic risk applied to individual chemicals is 1×10^{-6} and the target non-carcinogenic health index is one. Dermal absorption of surface water related to recreational activities indicated a slightly elevated risk at Hog Island Inlet. The Preliminary Risk Based Goals (PRBGs) for the recreational land use scenario for chemicals of concern for dermal absorption of surface water can be found in Appendix G-8, "PRBGs."

PRBGs calculated for the three principal chemical contributors to risk in the surface water due to dermal absorption are:

- benzo(a)anthracene 0.072 µg/l
- benzo(a)pyrene 0.0049 µg/l
- benzo(b)fluoranthene 0.048 µg/l

This information is included as part of the risk assessment for use as a tool only. Chemical specific PRBGs are guidelines that are individually protective of human health to a specified risk level. They are based on readily available information and do not take into consideration the additive effects of multiple chemical contamination exposure or exposure to multiple media types. They are meant to be used early in the decision-making process. A final remediation level is reached after appropriate analysis in the RI/FS.

6.10 HHRA Conclusions

Current laboratory analysis results indicate that non-carcinogenic hazards at Hog Island Inlet are within acceptable Wisconsin Administrative Code risk levels for both adults and adolescents engaging in recreational activities. Estimated excess lifetime carcinogenic risks are slightly elevated above acceptable Wisconsin Administrative Code levels for both adults and adolescents engaging in recreational activities.

7.0 Ecological Risk

This section presents supplemental Ecological Risk Assessment (ERA) information for Hog Island Inlet. The studies were performed to supplement the ecological risk evaluation conducted by the WDNR and presented in the document titled "Newton Creek System Sediment Contamination Site Characterization Report" dated December 1, 1995 (WDNR, 1995a).

The supplementary ecological risk assessment components focused on the sediments in Hog Island Inlet. Additionally, contaminant data from the water column was compared to chemical-specific ecological risk data available in the technical literature.

Sediment contaminant concentrations, benthic macroinvertebrate metrics, laboratory toxicity study results using sediments collected from the site, and other pertinent information from environmental studies in the scientific literature including sediment quality guidelines were integrated to assess concentration-effect relationships and ecological impacts.

7.1 Background

The WDNR performed an assessment in accordance with the *Guidance on Assessing Ecological Impacts and Threats from Contaminated Sediments* (WDNR, 1992) in 1993 and 1994 (WDNR, 1995a) for the Newton Creek system. The assessment concluded that ecological impacts were severe in the western and central part of Hog Island Inlet. The study included chemical analysis of sediments, toxicity tests *on Ceriodaphnia, Daphnia, Chironomus tentans* and *Hyalella azteca*, and benthic macroinvertebrate surveys. The WDNR study concluded that the effect levels to benthic macroinvertebrates for the Newton Creek system sediment contaminants of DRO and lead were the following:

	No Observed Effect Level (NOEL)	Lowest Observed Effect Level (LOEL)	Severe Effect Level (SEL)
DRO* (mg/kg)	81	150	1,280
Lead (mg/kg)	33	40	70

*It is important to note that DRO concentrations appear to be less in the current round of sampling when compared to 1993 and 1994 results. Decreases in DRO concentrations may be due to differences in laboratory methodology for DRO analysis. The Wisconsin Modified DRO method was revised and standardized in September 1995 (WDNR, 1995b), after the 1993 and 1994 DRO samples were analyzed. The integration method currently utilized may result in lower results than the method utilized 10 years ago.

7.2 Surface Water

The surface water analytical results shown in Table 5 were compared to the chronic water quality criteria for narcotic PAH chemicals (USEPA 2000a); Tier II chronic values calculated for chemicals (Suter, 1996); or National Recommended Water Quality Criteria (NWRQC) Continuous Concentrations (chronic) (CCC) for metals (USEPA 2002a).

The chronic National Ambient Water Quality Criteria (NAWQC) were intended to prevent significant toxic effects in chronic exposures but may be underprotective, as toxic effects to organisms have been documented at concentrations less than the chronic NAWQC (Suter, 1996). Tier II values were established so that chemical-specific aquatic benchmarks could be established with fewer data than required for the NAWQC. The NAWQC have been replaced by the NWRQC (USEPA 2002a).

As shown on Table 5, the chronic water criteria for lead and mercury were exceeded in the disturbed water sample from location HI02-29, and exceeded for lead in the disturbed water sample from WL-2.

Tier II values were exceeded for benzo(a)anthracene and benzo(a)pyrene in the disturbed water samples from HI02-29 and NC-Mouth. The Final Chronic Values (FCV) for benzo(a)anthracene and benzo(a)pyrene were not exceeded.

7.3 Sediment

In September 2002, surficial sediment samples were collected from Hog Island Inlet study locations HI-1, HI-13, HI-27 and from reference site location WL-2 in the west bay near Loon's Foot Landing. The samples were collected from the top 15 cm of the bed sediments and placed in five-gallon buckets. The sample buckets were subsequently homogenized at the LSRI. A portion of the homogenized sample was submitted for laboratory chemical analyses and the remaining sample was utilized for toxicity tests.

Concurrently, replicate sediment cores were collected from the same relative locations for macroinvertebrate survey (taxonomy analysis and enumeration) by LSRI.

Samples were collected in order from least to worst expected contamination (WL-2, HI-1, HI-27, and finally HI-13).

7.3.1 Chemical Data Evaluation

Tables 3 and 4 include the dry weight concentrations for the sediments. Chemical analysis was also performed on the laboratory control sediment from West Bearskin Lake used in toxicity testing. As shown on Table 13, "Ecological Risk Assessment Chemical Metrics," the percent differences in organic chemical concentrations were more than 20% higher in the sediments collected from the Hog Island Inlet sites (HI-1, HI-27, HI-13) compared to the organic chemical concentrations in the reference sediment sample (WL-2). Sediment DRO, PAH, and TEH contaminant concentrations progressively from HI-1 to HI-27 to HI-13.

Each of sediment samples at the study sites had concentrations below the previously calculated LOEL and SEL for DRO (150 and 1,280 mg/kg, respectively). However, decreases in current DRO concentrations compared to the 1993 and 1994 results may be due to differences in laboratory methodology for DRO analysis. The Wisconsin Modified DRO method was revised and standardized in September 1995 (WDNR, 1995b), after the 1993 and 1994 DRO samples were analyzed.

Each of sediment samples at the study sites had concentrations below the previously calculated SEL for Lead (70 mg/kg). Lead at HI-13 at 44 mg/kg was greater than the LOEL of 40 mg/kg. Lead at HI-27 at 38 and 33 mg/kg was equal to or greater than the NOEL of 33 mg/kg. Lead at HI-1 at 23 mg/kg was less that the LOEL.

The results of the TEH analyses performed on the homogenized sediments shown in Table 4 were utilized to evaluate the presence of other hydrocarbons that may be also be causing a negative impact.

PAH and metals mixtures were compared to sediment quality target values as discussed below.

7.3.1.1 Comparison to St Louis River Area of Concern Sediment Quality Targets (SQTs)

Hog Island Inlet and Superior Bay are a part of the St. Louis River Area of Concern (AOC). The St. Louis River AOC is one of the 43 designated AOC on the Great Lakes so designated because contaminated sediments result in restrictions on dredging for maintenance of channels, fish advisories, and habitat impairments to benthic organisms and those aquatic organisms who have life stages associated with the bottom sediments. The Minnesota Pollution Control Agency (MPCA) (Crane et al. 2000) along with other participants developed numerical SQTs for the following applications: 1) Designing monitoring programs, 2) Interpreting sediment chemistry data, 3) conducting ecological risk assessments, and 4) Developing

sediment quality remediation targets. The SQTs that MPCA has derived are preferentially from MacDonald et al. (2000).

Utilizing the probable effect concentrations (PECs) from the SQTs, quotients are calculated for each contaminant by dividing the contaminant concentration by the PEC value. PEC quotients (PEC-Q) from the individual contaminants are totaled and divided by the number of contaminants to yield a single mean PEC-Q based on the levels of all contaminants present. The mean PEC-Q has been evaluated for its predictive ability of toxicity. Table 13 shows the mean PEC-Q calculated for the study sites and the control and reference sites.

The mean PEC-Q increased progressively from the reference site and control sites (mean PEC-Q = 0.1), to the study sites HI-1 (0.2), HI-27 (0.2), and HI-13 (0.4). Some contaminants are more reliable predictors of toxicity than others (MacDonald et al. 2000). There are greater incidences of toxicity found when longer term tests are used (e.g., the 28 day *H. azteca* test). Generally, there is an increase in the incidence of toxicity with increasing mean PEC-Q. Using the descriptors and incidence of toxicity predicted from Crane et al. (2002), the reference and control sites at a mean PEC quotient of 0.1 or less would have low (< 10%) probability of being toxic to benthic macroinvertebrates. Study sites HI-27 and HI-1 with mean PEC-Qs of 0.2 and HI-13 with a mean PEC-Q of 0.4 would have moderate (< 50%) probability of being toxic to benthic macroinvertebrates. HI-13 at 0.4 is near the PEC-Q of 0.5 that is associated with a high (> 50%) probability of being toxic. There is a question whether incidences of toxicity up to 50% is acceptable in terms of impacts to benthic organisms over the long term. Moderate probability of up to 50% for incidences of toxicity to be occurring does not necessarily translate into a safe level of protection for benthic organisms. Protective levels for benthic communities may lie at mean PEC-Q between 0.1 and 0.2 which would roughly translate into the probability of incidences of toxicity of < 20% (MacDonald et al. 2000).

Figure 8, "2002 Sediment PEC-Qs and ESG TU's" shows the PEC-Qs calculated for each of the 2002 sediment sampling locations. Appendix E-2 includes the calculations for PEC-Q's.

7.3.1.2 Equilibrium Partitioning Sediment Guidelines (ESGs) for PAHs

USEPA's (2000a) ESGs for PAH mixtures to protect benthic organisms is based on a partitioning model that predicts the concentration of each PAH in the sediment pore water based on the organic carbon content of the sediments and partitioning coefficient of the PAH. The concentration of the PAH in the pore water is divided by the chronic toxicity value for that PAH to derive an ESG toxicity unit (ESG TU) value. The toxicity unit values for individual PAHs are

summed to yield a summed ($\sum$) PAH ESG TU value. If the summed TU value exceeds 1, sensitive benthic organisms may be affected by chronic toxicity. Based on an acute to chronic ratio of 4.16, if the summed TU value exceeds 4.16, lethal effects to sensitive species are expected. Between $\sum$ PAH ESG TU values of 1 to 4, only chronic effects are expected unless the species are unusually sensitive.

EPA (2000a) notes that the ESG guidelines that are calculated are based on narcotic toxicity only and do not consider enhanced toxicity that can occur if PAH-exposed organisms are simultaneously exposed to UV light. In environments where significant sunlight penetrates to bottom areas and benthic and/or epi-benthic organisms or sensitive early life stages of aquatic organisms such of fish reside for portions of their life cycles are exposed to UV light, the ESGs may be underprotective. USEPA (2000a) recommends that in areas where PAH contaminated sediments are present in shallow environments the risk of photo-activated toxicity is greater and a site-specific ESG may need to be generated that considers this potential risk. Given the enhancement of toxicity as it involves the survival endpoint for two of the test organisms (survival reduced approximately 50% in the *Hyalella azteca* and *Lumbriculus variegatus* test due to UV light exposure over already significantly reduced survival under lab light) and enhanced toxicity related to growth for the third (*Chironomus tentans*) at HI-13, ESG values unadjusted for UV light are underprotective in the case of the Hog Island Inlet sites. The $\sum$ PAH ESG TU value for HI-13 was 1.0 which is right at the threshold for predicting chronic toxicity. Given the enhancement of toxicity at HI-13 and also at HI-1 and HI-13, the chronic threshold of 1.0 and acute toxicity threshold of 4.0 in the ESG guidelines need to be adjusted downward in the case of Hog Island Inlet to address photoactivated toxicity. Based on the HI-13 results, the unadjusted threshold values of 1.0 and 4.0 may need to be divided by a factor of as much as 4.0 to yield summed TU values of 0.25 and 1.0 related to chronic and acute toxicity, respectively. If acute toxicity is defined as 50% or more mortality, than this level was equaled or exceeded at HI-13 after UV light exposure (52% reduction in survival of *Hyalella azteca* and 86% reduction in survival of *Lumbriculus variegatus*). These results were associated with the summed PAH ESG TU value of 1.0 at this site. Where UV light exposures are considered, the ESG TU value of 1.0 is associated with acute toxicity and a value of approximately 0.25 would be associated with chronic toxicity.

Another reason for the ESG TU values underestimating the toxicity as shown in the toxicity tests is that there may be other toxic compounds present in the mixture that are not analyzed for and are not a listed PAH included in the ESG TU calculations.

Figure 8 shows the PAH ESG TU values calculated for the 2002 sediment sampling locations. Appendix E-2 includes the calculations for ESGs.

7.3.1.3 Equilibrium Partitioning Sediment Guidelines (ESGs) for Metals

While comparison of the dry weight values for several of the metals to the TEC values indicates the potential for impacts, the subsequent evaluation of ESGs for the SEM-AVS metal analysis (USEPA 2000b) indicates that the metals present would not likely cause chronic or acute toxicity. Calculations are included in Appendix E-2.

7.3.1.4 Sediment Chemistry Relationships

Figure 9, "Relationships of Sediment Chemistry to Sediment Quality Targets" illustrates very strong relationships between the TPAH and DRO, TEH, Mean PEC-Q (PAHs, Metals), and PAH ESG TU's.

7.3.2 Toxicity Test Data Evaluation

LSRI conducted toxicity tests utilizing homogenized sediment samples from Hog Island Inlet study sites HI-1, HI-13, HI-27 and reference location WL-2. A lab control sediment from West Bearskin Lake was also used.

28 day toxicity solid-phase sediment exposures were performed with the scud *Hyalella azteca* and 10-day toxicity solid-phase sediment exposures were performed with the insect midge larvae, *Chironomus tentans*, and the oligochaete worm *Lumbriculus variegatus.* The endpoints of survival and growth were examined for each test species. A second series of tests was conducted for each species to determine whether toxicity would be enhanced by exposure to the ultraviolet light component of natural sunlight. The latter is not normally present under normal laboratory lighting conditions. Details of the test procedures and results are included in the LSRI report in Appendix E-1.

Table 14, "Ecological Risk Assessment Toxicity Test Results" presents the toxicity test mean survival rates and mean weight/individual for each of the three test organisms under normal laboratory light and under ultraviolet light exposure conditions. Toxic effects were found in sediments from Hog Island Inlet using the standard toxicity tests (as noted by statistically significant differences between these study sites and the reference site and/or the West Bearskin Lake laboratory control sediment in terms of survival and weight differences).

7.3.2.1 Standard Laboratory White Light Exposure Conditions

Statistically significant ($p < 0.05$) reduced growth and survival were observed in the 28 day *Hyalella azteca* test at HI-1. Reduced survival was observed in *Hyalella azteca* at HI-27, however since $p=0.35$ only

a 65% confidence interval can be associated with this result. Significant reduced survival was observed in the *H. azteca* test at HI-13.

Significant reduced survival and growth was observed in the 10 day *Lumbriculus variegatus* test at HI-13.

Significant reduced growth was observed in the 10 day *Chironomus tentans* test at HI-13.

7.3.2.2 UV Light Exposure Conditions

Statistically significant ($p < .05$) reduced survival was observed at HI-13 in the 28 day *H. azteca* test under UV light and significant reduced growth was observed at HI-1.

Significant reduced survival and weight were observed at HI-13 in the *L. variegatus* test.

Significant reduced growth was observed at HI-1 and HI-13 in the *C. tentans* test under UV light.

Exposure to UV light greatly enhanced the toxicity at the HI-13 site for *Hyalella azteca* and *Lumbriculus variegatus* related to the survival endpoint (decreased survival by approximately a factor of two, compared to lab light only induced toxicity) and to a smaller degree for *C. tentans* for the growth endpoint.

UV light exposures to *Chironomus tentans* at HI-1 decreased growth more so than exposure to lab light alone.

7.3.2.3 Relationship of Sediment Chemistry to Toxicity

Figure 10, "Relationships of Sediment Chemistry to *Hyalella azteca* and *Lumbriculus variegatus* Survival Endpoints in Toxicity Tests" illustrates a strong relationship between the sediment chemistry and the toxicity test survival results for the *Lumbriculus variegatus* standard white light and UV toxicity test results and *Hyalella azteca* UV test results. A strong relationship was not exhibited between sediment chemistry and the *Hyalella azteca* standard white light toxicity test results for the survival endpoint.

7.3.3 Macroinvertebrate Community Status Evaluation

LSRI performed macroinvertebrate identifications and enumerations survey of in five replicate sediment cores collected at each of the Hog Island Inlet study locations, HI-1, HI-27, and HI-13 and reference location WL-2 in the west bay of Loon's Foot Landing. Details of the procedures and results are contained in LSRI's report in Appendix E-3. The report also includes a supplemental evaluation and comparison of previous surveys conducted on Hog Island Inlet sediments.

Table 15, "Ecological Risk Assessment Sediment Macroinvertebrate Survey Metrics" summarizes for each location the following metrics: Total Abundance, Abundance and % of Dominant and other taxa (oligochaetes, chironomids, mollusca, and the amphipod *Gammarus fasciatus*), Taxa Richness, Shannon-Wiener diversity values, Biotic Index, Jaccard Coefficient of Community, and the Community Similarity Index.

The LRSI report in Appendix E-3 compares the recent macroinvertebrate study results with the previous studies conducted at Hog Island Inlet. The differences in the timing (seasonal) of collection, sample locations within the area of the site, and environmental variables generally does not make it possible to compare study results. It is very likely that differences found between some of the studies are mainly related to differences in the sampling season rather than to any demonstrable improvements in the quality of sediment or surface water

As shown on Table 15, total abundance was much higher in the HI sites compared to the reference site, with the greater abundance due to the increasing presence of dominant pollution tolerant species including oligochaetes, mollusca and the amphipod *Gammarus fasciatus.* Total chironomid abundance decreased between the reference site and HI sites.

As shown on Table 15, The chironomid/oligochaete ratio at all three sites (HI-13, HI-27 and HI-1) in the inlet were less than one and significantly reduced compared to the ratio at the reference site Similarly, in Great Lakes harbors that have received organic inputs, the chironomid/oligochaete ratio is typically less than one, indicating the dominance of oligochaetes. Ratios of less than one can be an indicator of organic inputs and/or nutrient enrichment. Under such conditions there are generally greater populations of oligochaete species and less of chironomid species (Kilgour et al 2000, Krieger, 1984).

Diversity as measured by the Shannon Diversity index was significantly reduced at sites HI-1 and HI-27 when compared to the reference site. HI-13 was slightly reduced when compared to the reference site. The Shannon Diversity index (SW index) takes into account species richness and the proportion of each species within the entire population to provide a measure of the overall population's diversity. The SW index reaches its highest value when all species are distributed evenly (same relative abundance), with corresponding lower index values when few species dominate the overall abundance. The former is considered a more natural community. The index usually decreases as habitat quality decreases. As species diversity decreases, ecosystem productivity, stability, and sustainability

decrease (Newman et al. 2000). The SW index should be used in conjunction with other indices and metrics in evaluation of benthic community status. Appendix E-4 includes the Shannon Diversity index value calculations.

In general, the macroinvertebrates identified in the Inlet are considered to be very tolerant to organic enrichment and are indicators of poor water quality and organic enrichment in the bottom sediments. As shown on Table 15, the Biotic Index (BI) for each site in Hog Island Inlet was significantly different ($p<0.05$) from the reference site. The calculated BI for each of the locations correlates to "severe organic pollution" in Hog Island Inlet and "significant organic pollution" for the reference site. Organic enrichment is believed, for the most part, to be due to the residual petroleum contamination present in the sediments of Hog Island Inlet. Tolerance values utilized in the calculation were taken from Benthic MacroInvertebrates in Freshwaters – Taxa Tolerance Values, Metrics, and Protocols (Mandaville, 2002) which includes tolerance values collected for use in Wisconsin streams (Hilsenhoff, 1982). Tolerance values were compared and found to be similar to those provided in the Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (Barbour, et al 1999). BI calculations are included in Appendix E-4.

HI-1 mean taxa richness was approximately equal to that at the reference site. Mean taxa and composite richness was reduced at sites HI-13 and HI-27 when compared to the reference site. A p value of <0.10 for HI-13 indicates a greater than 90% confidence that the mean taxa richness is different from the reference site. A p value <0.20 for HI-13 indicates a greater than 80% confidence that the mean taxa richness is different from the reference site.

The Jaccard Coefficient of Community (USEPA, 1990) was calculated for each HI site relative to the reference site. Calculations are included in Appendix E-4. This metric measures the degree of similarity in taxonomic composition between two stations (in this study between the HI sites and the reference site) in terms of taxa presence or absence and discriminates between highly similar collections. Coefficient values range from 0.0 to 1.0 and increase as the degree of similarity with the reference site increases. Review of values presented in Table 15 indicate a 68% difference between the reference site and any of the HI sites which indicates that there are large differences in species composition between the Hog Island Inlet sites and the reference site.

Community Similarity Index (USEPA, 1990) was calculated for each HI site relative to the reference site. Calculations are included in Appendix E-4. This metric is used to determine whether shifts in community assemblages have occurred along a stream gradient or above or below a pollution impact. Values range from 0 to 100%. The

higher the percentage of Index of Similarity value, the greater the similarity between the benthic communities at the study site compared to the reference site. Review of values presented in Table 15 indicate a greater than 50% difference in the Similarity Indexes between the reference site and any of the HI sites which again is an indication of differences in species composition between the HI sites and the reference site.

7.3.3.1 Relationship of Sediment Chemistry to Benthic Indices

Figure 11, "Relationships of Sediment Chemistry to Benthic Macroinvertebrate Community Abundance and Taxa Richness" illustrates a strong relationship between the sediment chemical metrics and total abundance, oligochaete abundance and chironomid abundance.

A fairly strong relationship is also illustrated between the sediment chemical metrics and taxa richness.

7.4 Other Relevant Studies

This section summarizes several research studies conducted by the USEPA or WDNR in association with the Hog Island Inlet site.

7.4.1 Ankley/ASCI 1991

Historical toxicity testing by AScI (an on-site USEPA contractor) in the early 1990s involving fathead minnow larvae placed in water for 96 h over contaminated sediments collected in Hog Island Inlet near the mouth of Newton Creek, resulted in 80% and 65% mortality in two testing events. Mortality to *H. azteca* in the same tests was 70% and 60%. Reference sediment at no time caused greater than 20% mortality to the test organisms. (G.T. Ankley of AScI letter to WDNR of September 19, 1991). The AScI conclusion at the time was that the toxicity appeared to be consistent through several seasons and is acute in nature for a number of species. The data indicated that the potential existed for adverse toxic impacts upon Hog Island benthic and fish communities.

7.4.2 Ankley, et al 1994

The objective of the study was to determine the toxicity of PAH contaminated sediments under standard laboratory fluorescent light vs. fluorescent plus UV light, designed to mimic low intensity sunlight.

It was noted that for the *Hyalella azteca* and *Lumbriculus variegatus* test organisms that survived the laboratory fluorescent light only exposure without UV, that there was significant mortality when the organisms were subsequently exposed in water to UV light for 2 hours. This would indicate a bioaccumulation of phototoxic compounds from the sediment into tissues that were photoactivated upon exposure to UV light.

A study conclusion was that laboratory assays conducted with sediments in the absence of UV light have the potential for underestimating toxicity. The study data also suggest that it may be prudent for proposed sediment quality criteria for photoactivated PAHs to address the issue of photoinduced toxicity.

The table below summarizes the results of the 10-day sediment toxicity tests for three benthic species under a 16:8 h light regime where the light hour exposure was made up of laboratory fluorescent light + ultraviolet light.

Sample	Test Organism	% Survival	µg TPAH/g OC	Bulk µg TPAH/g
Control	*Hyalella azteca*	80	1.61	0.11
	Lumbriculus variegatus	92.5		
	Chironomus tentans	100		
Reference Site	*Hyalella azteca*	77.5	47.42	1.66
	Lumbriculus variegatus	97.5		
	Chironomus tentans	100		
PAH 2	*Hyalella azteca*	72.5	52.14	2.14
	Lumbriculus variegatus	87.5		
	Chironomus tentans	100		
PAH 3	*Hyalella azteca*	0 [1.]	154.23	1.08
	Lumbriculus variegatus	0 [1.]		
	Chironomus tentans	100		
PAH -1	*Hyalella azteca*	2.5 [1.]	169.29	10.32
	Lumbriculus variegatus	0 [1.]		
	Chironomus tentans	100		

1. Indicates a significant decrease in survival under UV light.

7.4.3 Monson et al, 1995

The objective of the study was to evaluate the in situ phototoxicity of PAH-contaminated sediments to the oligochaette *Lumbriculus variegatus.* A site in the Newton Creek system was used as the field study site. Field and laboratory results are summarized in the table below. Sunlight exposed and shaded test chambers set on the bottom were used. Survival of *Lumbriculus variegatus* at the PAH-contaminated site was significantly less in chambers exposed to sunlight than in chambers held in the dark, or chambers from the reference site. Concurrent laboratory studies with sediment collected

from the two sites and an artificial UV light source corroborated observations made in the field. An important finding in the study was the relatively low levels of UV light that consistently affected survival at the contaminated site. The concurrence of laboratory and field test results underscores this observation. Although the laboratory light intensity was greater than concurrent measurements in the field, the laboratory light regime was not unrealistic relative to levels potentially encountered in the field. A summary of the study results are shown below.

Results of the Monson et al. (1995) Phototoxicity Study Using Newton Creek System Sediments

Test Date	Site	Light Regime		% Survival	µg TPAH / g OC	Bulk µg TPAH/g
Oct. 21, 1993 (Field)	Field Ref.	Light	7 days of natural sunlight. Test chambers on bottom	100	0.14	0.002
	Study Site	Dark		85	78.69	2.19
	Study Site	Sun Light		37 [1.]		
Nov. 2, 1993 (Field)	Field Ref.	Light	7 days of natural sunlight. Test chambers on bottom	100	0.14	0.002
	Study Site	Dark		85	37.73	3.53
	Study Site	Sun Light		60 [1.]		
Nov. 3, 1993 (Lab)	Control	UV Light	10-d 16:8 UV light:dark photoperiod	100	Assume ND	Assume ND
	Control	Dark		100		
	Ref	UV Light		100	0.14	0.002
	Ref	Dark		100		
	Study Site	UV Light		0 [1.]	37.73	3.53
	Study Site	Dark		88		

1. Statistically significant difference ($p < 0.05$) from dark treatment.

7.4.4 Patnode et al. 1995/1996

The objectives of the study were to compare exposure in swallow nestlings in the Newton Creek and a reference site in the Nemadji River Basin, examine the potential screening capability of liver enzyme induction, and document impacts of petroleum hydrocarbons on reproduction. The basic findings of the Patnode et al.study were:

- Petroleum hydrocarbons were not detected in 14 day-one carcass homogenates from either site.
- Males may forage as far as Newton Creek (1-2 km) resulting in a positive detection within the GI tract of a Nemadji River nestling.

- Since both aliphatic and aromatic petroleum hydrocarbons are readily metabolized, the analysis that was used can only detect recent exposure.
- In Newton Creek, hatching success was significantly reduced at the study site compared to the control site for a 2-year period ($p=0.0036$).
- Sediments from the control site had nondetectable to background concentrations of petroleum hydrocarbons
- Petroleum hydrocarbons were detected in gastro-intestinal tracts of a single nestling from the control and a single nestling from the study site in 1995, but not in any samples in 1996.
- Chronic exposure to aromatic hydrocarbons was suggested by significant induction ($p=0.056$) of liver EROD activity in day 12 nestlings from the Newton Creek basin compared to the Nemadji River
- Insect larvae containing hydrocarbon body burdens from being in contact with the contaminated sediments, emerging as the flying adult life form and consumed by tree swallows, is the most likely exposure and uptake route. Flying adults from chironomid larvae, can become a significant portion of the diet of not only swallows but also bats, redwing blackbirds, terns, and amphibians. Many species of birds time their breeding cycles to take advantage of the seasonally abundant supply of emergent insects.
- The data are sufficient to conclude that the contaminated sediments in Newton Creek, through the above discussed route, likely caused the increased EROD activity.
- There is no attempt by Patnode et al. to link EROD induction to adverse ecological effect. The study was an attempt to use the EROD activity as a screen to show exposure to hydrocarbons has occurred.
- Conclusions regarding ecological risk are warranted because the significant EROD induction indicates exposure to hydrocarbons in the Newton Creek system has occurred and, most importantly, the significant reduction in hatching success that has correspondingly occurred at the Creek site.

7.4.5 Kosian, et al, 1998.

Pore water obtained from sediments collected from the Newton Creek system were toxic to *Lumbriculus variegatus* following exposure to UV light, while organisms exposed to the same pore water without UV treatment showed no toxic effect. Solid phase extraction (SPE) disks and high-performance liquid chromatography were used in

conjunction with the *Lumbriculus* toxicity tests, to extract and fractionate phototoxic chemicals from the pore water. Phototoxic fractions analyzed by gas chromatography-mass spectrometry revealed the presence of a number of aliphatic hydrocarbons, substituted PAHs, and PAHs containing heteroatoms.

Chemicals were screened for their phototoxic potential based on empirical data and predictive models. A refined list of PAHs was then evaluated in the basis of their phototoxic potency as defined by the recently developed quantitative structure-activity model and estimation of their bioaccumulation potential. Based on the model predictions of potency and bioaccumulation, nine likely phototoxic chemical were identified.

The study was successful in using SPE technology in conjunction with phototoxicity assays to characterize the nature of the toxicants (i.e., nonionic organics) in sediment pore water. They were also able to partially complete phase II of the TIE by developing a list of compounds identified via GC-MS, that based on QSAR models and estimates of bioaccumulation potential, were likely candidates in causing phototoxicity. Comparing concentration estimates of the identified compounds with actual toxicity data to further define the suspect toxicants could not be done because most of the compounds were substituted PAHs for which no toxicity data exists.

The study analysis highlighted that substituted PAHs were contributors to toxicity. The fractionated organic compounds obtained from the site pore water were fairly complex due to the numerous components. This complexity may have hindered the identification of other possible phototoxic compounds during the GC-MS analysis.

There is uncertainty as to possible chemical losses of other phototoxic compounds associated with the extraction and fractionation process on the original pore water.

The data shows that the fractionated complex mixtures causing phototoxicity derived from the common ring structures in the samples, combined with their predicted or demonstrated phototoxicity, emphasizes the potential importance of these more unusual PAH structures in determining the phototoxicity of environmental mixtures of PAHs.

Based on the presumption that the photoactivated toxicity of PAHs is additive, environmental samples containing large numbers or concentrations of unusual or substituted ring structures might have substantial phototoxicity not directly predicted on the basis of concentrations of common, unsubstituted PAHs alone. This may be particularly true for PAH sources such as unweathered petroleum which can contain high concentrations of substituted and heterocyclic PAHs.

7.4.6 West, et al . 1998.

The objective of the study was to develop and utilize a novel method to document the behavioral response of the oligochaete *Lumbriculus variegatus* to a variety of contaminated sediments in the laboratory. Sediments collected from Hog Island Inlet were used in the study. Avoidance responses of *Lumbriculus variegatus* to contaminated sediments were compared to those from the West Bearskin Lake reference sediment.

One of the sites that exhibited a significant avoidance of the sediments by *Lumbriculus variegatus* was the oil/PAH contaminated sediments from Hog Island Inlet. The study suggested that the avoidance reaction may provide a useful component of a suite of tests to characterize the potential effects of sediment-associated contaminants on the benthos. However, since physical characteristics of the sediments can influence behavior, it cannot be unequivocally concluded that the response of the oligochaetes was due solely to contaminants.

One of the study conclusions was that the validation of the laboratory results by field studies to determine its predictive capability is needed. The results of the laboratory avoidance testing for the Hog Island Inlet studies are summarized in the table below.

Test Sediment	Number of Replicates	Duration (h)	% Recovered from Reference Sediment	% Recovered from Hog Island Sediments
Hog Island 1	2	72	93.3	83.3
Hog Island 2	2	72	93.3	0 [1.]
Hog Island 3	2	72	93.3	28.3 [1.]
Hog Island 4	2	72	93.3	0 [1.]
1. Indicates significant difference from the reference site.				

7.4.7 West, et al 2001.

The study evaluated the effectiveness of a carbonaceous resin in reducing bioavailability of PAHs in contaminated sediments. Resin as an in situ sorbent addition may provide a remediation option. Sediments collected from Hog Island Inlet were used in the study.

In laboratory studies, oligochaete worms actively avoided untreated Hog Island sediments, with no worms recovered from the sediment compared with 93.8% recovered from the reference sediment.

All of the oligochaete worms recovered from the 28-d bioaccumulation test using untreated and resin amended Hog Island sediments that were subsequently exposed to UV light in clean water for 24 hours died within 3.7 h of UV exposure. Concentrations of PAHs in oligochaete tissues from the untreated Hog Island sediments was 2,374 µg/kg.

Responses of the oligochaetes in the Hog Island sediments suggests the 8 unsustituted PAHs measured for in the study may not have been the only toxicants of significance in the sediments. The Kosian et al. (1998) study is referenced to link the biological responses in the resin-treatment study to the toxicity possibly attributable to substituted and heterocyclic PAHs not measured in the resin study.

7.4.8 Diamond, et al 2003

In 2002, the USEPA (Diamond, 2003) conducted a photo activated toxicity study utilizing amphipods of the genus *Gammarus* collected from sites with known PAH contamination, including Hog Island Inlet. The organisms were collected in the Inlet near the mouth of Newton Creek.

Tissue analysis indicated that PAH compounds were accumulating in the amphipods. The PAH concentration in *Gammarus* tissues collected from Hog Island Inlet was 3,471 (SD 966) µg/kg wet weight with identified PAHs (16 parent) contributing 348 µg/kg to the total. Assuming that Gammarus is 90% water, the dry weight concentration of total PAHs was 34,710 µg/kg and identified PAHs was 3,480 µg/kg. The majority of PAHs were unidentified PAHs (peaks with retention times between 8 and 23 minutes.

Amphipods collected from two PAH-contaminated locations and exposed to natural sunlight died significantly faster than amphipods collected from an uncontaminated reference location. After 30 hours in sunlight, there was 95% mortality in the amphipods collected from Hog Island Inlet and 5% mortality in the reference site amphipods.

The test results indicate that organisms residing in PAH contaminated environments can accumulate PAH concentrations sufficient to be at risk for photoactivated toxicity.

Diamond (2003) notes that *Gammarus* may not be at risk from photo-activated toxicity because of their behavior but they are ideal surrogates for species who have other behavior traits that would be expected to inhabit contaminated sites. The study does illustrate that significant PAH photoactivated toxicity exists for many organisms that would typically reside in the habitats involved. Species particularly at risk would be those that are protected in adult life stages but have highly sensitive early life stages that lack protective features and/or reside in areas that receive high UV doses such as shallow or clear water (Diamond, 2003).

7.5 Risk Description

7.5.1 Association of Contaminant Concentrations and Effects

As shown in Figure 10, the TPAH dry weight concentrations in Hog Island Inlet appeared to show good correlation to the toxicity test results.

Good correlations also exist between other chemistry measurements (DRO and TEH) and the sediment quality guideline values (PEC-Q and PAH ESGTUs) and the toxicity test results.

In the toxicity testing, it appears the concentration threshold for TPAHs associated with no or lowest observed effects is in the 2 to 3 mg/kg range. Acute toxicity can be associated with a TPAH threshold concentration of 7.5 mg/kg TPAHs .

Figure 11 shows the relationship of a number of benthic metrics to sediment chemistry measurements and sediment guideline values. Correlations are generally good in showing decreases in the benthic metric values as the contaminant concentrations increase.

The unique aspect of petroleum hydrocarbon contamination is that depending on the weathered state of the hydrocarbons, microbial activity, microhabitats occupied and exposure routes, and what toxic components are present, the various mixtures can either be toxic to benthic associated organisms or can serve to stimulate populations that are tolerant to the degree of organic pollution present. Appendix E-5 reviews pertinent literature and discusses some site results in the above context of the dual effects.

7.5.2 Integration of Lines of Evidence

Table 16, "Integration of Measurement Endpoints for Assessing Impacts of Contaminated Sediments to the Benthic Community" integrates the results from the multiple measurement endpoints (sediment chemistry, toxicity tests, benthic community studies, and bioaccumulation) to reach possible conclusions about the degree of effects and impacts of contaminants on benthic macroinvertebrate community health. The integration of multiple measurement endpoints in a weight-of-evidence approach has the potential to reduce uncertainty associated with risk assessments and as such, improve management decisions in regard to contaminated sediments (USEPA, 2002).

7.5.3 Likelihood of Risk

The likelihood of significant ecological risks and impacts to the benthic invertebrate community and pelagic invertebrate and fish community is considered high. Toxicity test results and benthic community survey results support this conclusion. The PAH sediment concentrations at the Hog Island Inlet sites exceed several of the

sediment guideline TEC's and PEC's for individual PAHs based on the protection of benthic macroinvertebrates.

The likelihood of risk to the benthic community from chronic exposures is high because the benthic organisms are generally sedentary and confined to small areas of bottom sediments. Likewise the risk to the pelagic community from acute toxicity is high for immature species such as fish if spawning and egg deposition occurs on the surface of sediments that are contaminated. Risks to eggs and larvae are increased concurrent with disturbance of the contaminated sediments.

7.5.4 Additional Risk Information

Additional information is presented to consider future risk scenarios associated with the deeper contamination.

7.5.4.1 Other Organic Contaminants

As shown on Table 4 several other organic contaminants besides PAHs and VOCs were detected at the site. Total organic contaminant concentrations increased as the corresponding PAH concentrations increased, as shown on Figure 9.

These include the heterocyclic aromatic hydrocarbons (HAHs) Dibenzothiophene and Dibenzofuran. In general, these compounds appear to be co-located with PAH and VOC compounds. The environmental impacts of the presence of the HAHs is unknown. Certain HAHs, even when present in relatively low concentrations, may have greater impacts than that of PAHs (Adams and Giam, 1984).

Appendix E-5, Section 1 includes further review of literature regarding potential toxicity associated with other organic contaminants.

7.5.4.2 Other Exposure Considerations

Exposure to petroleum hydrocarbons by young fish may be sublethal at early life stages but may lead to mortality later in life by increasing the vulnerability of these fish to disease, parasitism, or predation. Exposures may exhibit a variety of adverse effects, and although these frequencies are often low, the cumulative impact on the exposed populations may be substantial (Heintz et al. 1999). Other considerations (Petersen et al. 1998) include: Early life stages of fish are considered to be the most sensitive life stage. The relative lipid content is in early life stages is higher in the juvenile/adult stages. The early life stages will accumulate higher body burdens of lipophilic chemicals like PAHs per kilogram of total weight from the surrounding contaminated water through bioconcentration. Biotransformation of xenobiotics in embryonic and larval stages was indicated to be insignificant compared to the juvenile and adult stages. PAHs will primarily accumulate in the yolk sac lipids which act as a

toxicant sink during the embryonic and early larval stages. During development of the larvae, PAHs sequestered in the yolk are transported to sensitive organs in which the toxic action or metabolism to toxic reactive intermediates occur. Due to the higher gill surface (and surface in general) to weight ratio in larvae, time to steady state and thus to a "toxic dose equilibrium" is reached sooner in early life stages than in juvenile/adult stages. In addition to the exposure of waterborne xenobiotics, early life stages of fish may be exposed to PAHs by a transfer from parental fish to developing gametes.

Recent studies in Alaska (Heintz et al. 1999; Carls et al. 1999) where the fish eggs, embryos, and larvae were exposed to PAHs released from deposited oils in stream bottoms showed that the lowest observed effect concentrations (LOECs) ranged from 0.4 to 1.0 µg/l depending on the species. The LOEC values were based on sublethal responses which included malformations, genetic damage, decreased size, and inhibited swimming that lead to mortality. Increased mortality to salmon embryos occurred when they were exposed to initial aqueous TPAH concentrations of 1.0 µg/L. By inference, the immature life stages of other fish species may be similarly sensitive to low level exposures to dissolved PAHs in the water column. Enhanced toxicity of PAHs as a result of photoactivation by UV light has been well documented but the experimental setup did not allow for the activation of a significant portion of the PAH molecules. However, photoactivation at the site after the oil spill was likely. Thus the lowest observed effects concentrations in the study that were measured (0.4 µg/L) may actually be conservative compared to the actual on-site conditions due to the spill.

Bottom areas that have relatively unweathered oil associated with them may act as toxic reservoirs that may persist for years until dispersed by a disturbance event. Thus, long-term effects resulting directly from oil exposure are long term in the sense that the PAHs leach over time scales measured in generations. Heintz et al. (1999) made the following observation: "The adverse effect found for embryos exposed to low part-per-million TPAH concentrations reported here by Carls et al. (1999) suggests that restoration of habitats chronically polluted with PAHs may be even more difficult than previously appreciated. The larger more toxic PAHs will most likely persist longest at locations where PAHs are continually leached into receiving aquatic habitats. The effects of these PAHs on organisms in these habitats may be sublethal at early life stages but may lead to mortality later in life by increasing the vulnerability of these organisms to disease, parasitism, or predation. In our experiments, embryos exposed to PAHs exhibited a variety of adverse effects, and although the frequencies of these effects were often low, the cumulative impact on the exposed populations may be substantial."

7.5.4.3 Potential for Natural Recovery

The potential for the natural recovery of the contaminated sediments is low. Long chain, high molecular weight PAHs such as benzo(a)pyrene and benzo(a)anthracene are generally considered to be biorecalcitrant, and not expected to biodegrade quickly in sediments without pretreatment with oxidizing agents to chemically break bonds. Current research is being conducted to explore the in situ anaerobic biodegradation of long chain PAHs beneath sediment caps. However, conclusive evidence has not yet been documented regarding the success of natural microbial degradation of long chain PAHs.

In the hypoxic or anoxic conditions of the sediments most PAHs are generally quite stable and may persist indefinitely in oxygen poor water basins or anoxic sediments.

The high levels of contaminants present that are integrated into the bottom substrates and present in the surface as NAPL, were likely released and deposited into the Inlet decades ago. That these conditions still exist after so long a period of time would indicate that dependence cannot be put on natural attenuation as the primary remediation approach to deal with the problem in any effective manner.

7.5.4.4 Potential for Exposure to Deeper Sediments

The potential for disturbance of and subsequent exposure to the deeper more contaminated sediments is high. Potential disturbing activities include bioturbation from benthic macroinvertebrates, anthropogenic disturbance from shoreline maintenance or boat props, and heavy storm or northerly wind-induced wave actions where wave energies are transferred to the bottom of the water column over the sediments.

7.5.4.5 Potential for Risk beyond the Study Area

The contaminated sediments present risks to aquatic communities beyond the study area. In a hypothetical situation, a boat or intense storm with heavy waves could cause major disturbance, mixing, and resuspension of the sediments and NAPL. The effects of phototoxicity coupled with the exposure to the PAH contaminated suspended sediments and NAPL could result in severe impacts to the aquatic community beyond the limits of the study area.

7.5.5 Risk Description Summary

Based upon the review of the results of the supplemental ERA and recent literature, ecological risk associated with the contaminated sediments are highly likely for both current and future scenarios.

Contaminant presence leading to adverse biological effects related to degradations and alteration of the benthic community structure is evident. Bioaccumulation of sediment-associated contaminants has the

potential to adversely affect upper trophic level aquatic life and aquatic dependant wildlife.

Impacts to benthic organisms and immature fish are expected to be present the highest risks. Natural attenuation of the contamination is expected to be a very minimal over a long period of time.

7.6 Uncertainty Analyses

Several sources of uncertainties are associated with ecological impact studies. Categories of uncertainty include: conceptual model uncertainties; natural variation and parameter error; and model error.

7.6.1 Conceptual Model Uncertainties

Conceptual model uncertainties may be associated with the exposure pathways, chemicals of concern, and exposed components.

7.6.1.1 Exposure Pathways

Exposure pathways examined were limited to the direct exposure to sediments in the bioactive zone (0 to 15 cm) and overlying surface waters. However, exposures may occur deeper if tubificids and other oligochaetes burrow deeper into the sediments and expose the deeper contaminants. In freshwater environments, bioturbation by benthic organisms can extend down to 20 – 40 cm (Clarke et al. 2001).

7.6.1.2 Chemicals of Concern

Comparison of contaminants to sediment effects benchmarks was primarily related to PAHs, and metals. Many other chemicals were identified to be present including heterocyclic aromatic hydrocarbons such as dizbenzofuran, benzothiophenes and dibenzothiopenes. These chemicals may also contribute to the overall toxicity of the sediments. Additionally, see Appendix E-5 for a discussion of other toxic components of the petroleum oil mixture that may be present and contribute to toxicity.

A high relative percent difference in PAH concentrations was noted between the September and October 2002 sampling events at HI-1, HI-13, HI-27, and WL-2. The variation may be due to differing methodologies between Battelle and EnChem or due to spatial variation of the sampling locations in the sediments and heterogeneity of contaminant distribution.

Non-aqueous phase liquids (NAPL) have been observed in sediments during previous sampling events. The NAPLs have a strong hydrocarbon odor and cause sheening. The NAPLs likely contain a myriad of concentrated chemicals. The effects of exposure to the NAPLs was not directly evaluated in the supplemental ERA.

7.6.1.3 Exposed Components

The exposure of a variety of potential terrestrial organisms, aquatic plants, and phytoplankton to the contaminated sediments was not directly evaluated in this supplemental ERA. Exposure to the contaminants may also present a risk to these components.

7.6.2 Natural Variation

Natural variation uncertainties include substrate differences, spatial variation, and seasonal effects.

7.6.2.1 Substrate Differences

Variations exist in the sediments in the study area with regards to organic matter, organic content, and grain size. These variations likely have some effect on the benthic community and availability of contaminants.

7.6.2.2 Seasonal Effects

The taxa richness, species presence, and abundance of the benthic community likely vary with respect to seasonally and inter-yearly sampling times.

7.6.2.3 Spatial Effects

The three stations examined for the integration of data based on the measurement endpoints or lines of evidence collected represent a 15 acre area. Spatial variations are expected to occur over the entire area. This is evident in comparison of chemistry across the site, distribution of fines and total organic carbon, and variation of community abundance for replicates. It is believed that the sites selected were representative as to degrees of contamination present in various portions of the Inlet.

7.6.3 Model Limitations

Uncertainties related to the model include representativeness of the toxicity test species, test duration; limitations of comparative benchmarks, and statistical limitations.

7.6.3.1 Representativeness of Organisms for Toxicity Studies

Organisms selected for evaluation of sediment toxicity were based on recommended USEPA methods. These organisms have been successfully used in the past at other Great Lakes sites to predict toxicity. It has not been confirmed whether all of the test species are actually present in the local environment. However, the toxic effects observed are expected to represent effects on similar species.

7.6.3.2 Duration of Tests

The toxicity tests were only run for 10 days and 28 days. If the tests had been run for a longer duration it is expected that toxic effects would have been more clearly demonstrated for the less contaminated stations.

7.6.3.3 Statistical Limitations

It was not economically feasible to collect replicate samples for chemical analysis, and the number of replicate samples was limited for the community survey and toxicity tests. The limited data set is not considered to be statistically powerful.

7.7 Risk Characterization Summary

The integrated evidence from the supplemental ERA provides strong evidence of contaminant-induced degradation in Hog Island Inlet sediments related to the benthic macroinvertebrate community. Visually contaminated sediments in the central and northwestern end of Inlet are likely to be impacted based on the integration of measurement endpoints results. Contaminated sediments on the southeastern end of the Inlet with only secondary characteristics of contamination (Odor, FID reading) are probably to potentially impacted based on the integration of measurement endpoints.

It is unlikely the sediment contamination will naturally attenuate in the near future. Furthermore, long chain PAHs are expected to degrade only at very slow rates in the natural primarily anoxic sediment environment. High contaminant concentrations and NAPLs have been present in the sediments for decades and will continue to be present indefinitely unless remediated.

Future risks to the environment exist because the deeper sediments are more contaminated than those in bioactive zone, and a potential exists for disturbance from natural and anthropogenic forces. Studies indicate that if the sediments are agitated and resuspended, water quality will exceed the surface water quality values for chronic toxicity.

8.0 Cleanup Goals – Preliminary Considerations

The overall cleanup goals for Hog Island Inlet should consider ecological risks, human health risks, and contaminant transport mechanisms. Remediation options for the contaminated sediment of the Inlet should be designed to achieve an established sediment quality objective to the extent practicable. Practicality in achieving the sediment quality objective is defined by considering net environmental effects, including health, safety and welfare, natural recovery rates, engineering feasibility, costs, and compliance with applicable laws and regulations.

It appears that contamination in the surface water may pose unacceptable cumulative human health risks for recreational users of the Inlet. Contamination in both the surface water and the sediments pose likely to probable impacts to the benthic macroinvertebrate community and therefore unacceptable ecological risks to this important component the nearshore area of the St. Louis River and Lake Superior ecosystem. The relative degree of impact and risk depends on the spatial location of the bottom sediment area in the Inlet. The degree and extent of residual petroleum-related contamination and the associated impacts to the benthic community will need to be considered in management decisions that are made for the site in relationship to remediation alternatives.

Visual identification of contaminations is reasonable for contamination associated with more acute-related or severe effect levels to benthic macroinvertebrates, but not for chronic protection.

If cleanup goals are based on human health and/or acute ecological protection (5 to 7.5 mg/kg TPAH), the visually contaminated sediment volumes for remediation would be approximately 20,000 cubic yards. If cleanup goals are based on chronic ecological protection (2 to 3 mg/kg TPAH), the sediment volumes for remediation would likely be approximately 40,000 cubic yards. Cleanup goals based on aesthetic values (odors) for future uses such as recreational swimming may result in higher cleanup volumes

9.0 Conclusions

This section summarizes the conclusions of the previous sections.

9.1 Contaminant Distribution, Fate, and Transport

PAH concentrations appear to have stayed consistent with 1995 sampling. Differences in DRO results between the sampling events may be related to the analytical methodologies used by the different laboratories involved rather than to actual changes in concentrations over time of DRO in the sediments.

Generally, the surficial sediments (0-15 cm) do not appear to be cleaner than deeper sediments (0-4 ft). Sediment contaminants are easily suspended into the water column.

Visual identification of contaminated sediments appears to be reasonable based on limited sampling. Sediments in Segment L are visually contaminated. The area of visually contaminated sediments in HI Inlet is mainly in the central and northwestern end, which includes the 1995 proposed area of remediation. Scattered areas of visually contaminated sediments exist throughout the inlet, beyond the 1995 proposed remediation area.

9.2 Human Health Risk

The HHRA indicates that risks from exposure to the surface water may exceed target risk levels and are higher than originally calculated in the 1995 human health risk assessment (WDNR, 1995a). The increased risk calculations are primarily based upon the consideration of PAH compounds which were previously not considered due to data quality considerations.

9.3 Ecological Risk

Integration and evaluation of the evidence from the supplementary ecological risk assessment indicates that it is highly likely contamination identified in Hog Island Inlet sediments pose ecological risks to the benthic macroinvertebrate community. This is consistent with the 1995 WDNR study conclusions.

Evidence includes sediment chemistry, toxicity study results, and benthic macroinvertebrate community metrics.

Toxicity test results indicate that sublethal ecologically undesireable impacts to the benthic community begin at threshold TPAH concentrations greater than 2 to 3 mg/kg. Acute impacts appear to occur at TPAH concentrations greater than 5 to 7.5 mg/kg. Toxicity study results indicate that photo-activated toxicity increased with exposure to ultraviolet light in the laboratory that simulated ultraviolet light levels measured in the field at Hog Island Inlet.

A strong dose response relationship appears to exist between PAH chemical concentrations and toxicity test results. There is also a strong relationship between PAH chemical concentrations and macroinvertebrate study results.

There is a strong positive relationship between PAH concentrations and the measurements for DRO and total expanded hydrocarbons. Likewise there is a strong relationship between PAH concentrations and the ecologically based sediment guideline values (Probable Effect Concentration Quotients and PAH Equilibrium Partitioning Sediment Quality Guideline Toxic Units.)

The Biotic Index metric for benthic community structure indicates that each study location in Hog Island Inlet is severely polluted as it relates to organic pollution. It is believed that a large portion of the organic pollution present at Hog Island Inlet sites originates in residual petroleum hydrocarbons compounds. The reference location in Loon's Foot Landing appears to support a benthic community that is associated with somewhat less organic pollution based on the Biotic Index metric and other metrics. The dual effects of stimulation of a pollution tolerant populations and toxic effects to benthic organisms

based on the particular mixture of petroleum hydrocarbons present needs to be taken into account in regard to the benthic metrics.

Contaminant presence leading to adverse biological effects related to degradations and alteration of the benthic community structure is evident. Bioaccumulation of sediment-associated contaminants has the potential to adversely affect upper trophic level aquatic life and aquatic dependant wildlife.

Impacts to benthic organisms and immature fish are expected to be present the highest risks.

9.4 Cleanup Goals and Remediation Volumes

The overall cleanup goals for Hog Island Inlet should consider ecological risks, human health risks, and contaminant transport mechanisms. Remediation options for the contaminated sediment of the creek should be designed to achieve an established science-based sediment quality objective protective of human health or aquatic life to the extent practicable. Practicality in achieving the sediment quality objectives is defined by considering net environmental effects, including health, safety and welfare, natural recovery rates, engineering feasibility, costs, and compliance with applicable laws and regulations.

Visual identification of contaminations is reasonable for contamination associated with acute-related ecological risks, but not for chronic ecological protection. If cleanup goals are based on human health and/or acute ecological protection (5 to 7.5 mg/kg TPAH), the visually contaminated sediment volumes for remediation would be approximately 20,000 cubic yards. If cleanup goals are based on chronic ecological protection (2 to 3 mg/kg TPAH), the sediment volumes for remediation would likely be approximately 40,000 cubic yards. Cleanup goals based on aesthetic values (odors) for future uses such as recreational swimming may result in higher cleanup volumes.

10.0 Standard of Care

This report was developed in accordance with generally accepted professional practice at this time and location. Other than this, no warranty is implied or intended.

GGC/JM/MJB/JH/TJ/ls/JEG

11.0 References and Resources

(In addition to list of Project Documents listed in Section 2.0)

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Table 1
Analytical Methods
Hog Island Inlet Surface Water, Sediments, and Shoreline Soils

Parameter	Method	Laboratory	Hold Times	Containers	Preservation*
Aqueous Chemistry					
VOCs	SW 846 8260B	EnChem	14 days	(3) 40 ml glass vials	HCl
PAHs	SW 846 8270C	EnChem	7 days	1 liter amber glass	none
Total Organic Carbon (TOC)	EPA 415.2	EnChem	28 days	250 ml glass	H2SO4
Metals (Cd, Cr, Pb) except Hg & Cr+6	SW846 6020	EnChem	6 months	1000 ml plastic	HNO3
Hg	SW846 7470A	EnChem	6 months	1000 ml plastic	HNO3
Cr+6	SW846 7197	EnChem	24 hrs	500 ml plastic	none
BOD	SM 5210B	EnChem	48 hrs	1000 ml plastic	none
COD	EPA 410.4	EnChem	28 days	125 ml plastic	H2SO4
Oil & Grease	EPA 1664	EnChem	none	2 oz amber, 50 g soil	none
Total Suspended Solids (TSS)	EPA 160.2	EnChem	7 days	250 ml plastic	none
Sediment/Soil Chemistry					
Volatile Organic Compounds (VOCs)	SW 846 8260B	EnChem	21 days	2 oz glass, 20-35 g soil	20 ml MeOH
Polynuclear Aromatic Hydrocarbons (PAH)	SW 846 8270C	EnChem	14 days	8 oz amber, 250 g soil	none
Expanded PAH Hydrocarbons & Alkyl Subsititutes	Modified 8270	Battelle	7 days	1 l amber glass	none
Diesel Range Organics	WI DRO	EnChem	7 days	1 l amber glass	HCl
Total Organic Carbon (TOC)	SW946 9060M	EnChem	28 days	5 oz plastic, 50 g soil	none
Metals (except Hg & Cr+6)	SW846 6020	EnChem	6 months	5 oz plastic, 50 g soil	none
Hg	SW846 7471A	EnChem	6 months	5 oz plastic, 50 g soil	none
Cr+6	SW846 7196A	EnChem	30 days	5 oz plastic, 50 g soil	none
SEM/AVS Ratio Metals (Cd, Cu, Pb, Ni, Zn, Hg)	EPA Draft 1629	EnChem	14 days	5 oz plastic, 50 g soil	none
Sediment/Soil Geotechnical					
Grain Size Analysis	ASTM D422	EnChem	6 months	Glass or Plastic Quart Jars	none

Notes:

*All samples for chemical analyses stored and shipped in an insulated cooler packed with ice.

Table 2
Soil Analytical Results
Hog Island Inlet

Analytical Parameters	Generic RCLs in Soil	Boring No./Depth (ft)/Date										Relative Percent Difference for Dup
		HIS02-2	HIS02-2-DUP	HIS02-4	HIS02-6	HIS02-7	HIS02-9	HIS02-13	HIS02-18	HI02 S-21	WL-2A	HIS02-2
		0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-0.5'	0-1'
		10/3/02	10/3/02	10/3/02	10/3/02	10/3/02	10/3/02	10/3/02	10/3/02	10/3/02	11/20/02	10/3/02
PAHs (ug/kg)												
Acenaphthene	900,000	<24	<26	<21	<27	<23	<34	<34	<35	<23	<16	0%
Acenaphthylene	18,000	<18	43	<16	<20	<17	<26	<26	37	<17	<26	82%
Anthracene	5,000,000	38	140	<15	<20	<17	<25	39	34	<17	20	115%
Benzo(a)Anthracene	88	**210**	**290**	<17	<22	50	<28	34	37	39	42	32%
Benzo(a)Pyrene	8	**49**	**480**	<16	<20	**43**	<26	**34**	**40**	**24**	**40**	163%
Benzo(b)Fluoranthene	88	60	**150**	<14	<18	33	<23	31	48	24	40	86%
Benzo(k)Fluoranthene	880	23	160	<17	<21	37	<27	31	33	19	42	150%
Benzo(g,h,i)perylene	18,000	29	77	<15	<19	31	<24	38	43	24	27	91%
Chrysene	8,800	24	730	<17	<22	47	<28	63	98	57	49	187%
Dibenzo(a,h)Anthracene	8.8	<16	<17	<14	<18	<15	<23	<23	<24	<15	<11	0%
Fluoranthene	600,000	47	250	15	22	84	<22	47	110	52	100	137%
Fluorene	600,000	<18	37	<16	<20	<17	<26	<26	46	<17	16	69%
Indeno(1,2,3-cd)Pyrene	88	<17	33	<15	<19	26	<24	<24	25	<16	28	64%
1-Methylnaphthalene	1,100,000	<21	29	<18	<23	<20	<29	62	230	160	19	32%
2-Methylnaphthalene	600,000	<18	44	<15	<20	21	<25	120	350	240	31	84%
Naphthalene	20,000	<25	28	<22	<28	<24	<35	67	220	130	34	11%
Phenanthrene	18,000	33	150	<14	<18	61	<23	120	150	140	73	128%
Pyrene	500,000	330	1500	<15	31	92	<25	76	100	69	81	128%
Total PAHs		**843**	**4141**	**15**	**53**	**525**	**0**	**762**	**1601**	**978**	**642**	132%
VOCs (ug/kg)												
Benzene	5.5	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%
Carbon Tetrachloride		<25	<25	<25	<25	49	<25	<25	<25	<25	<25	0%
Chloroform		<25	<25	<25	<25	48	<25	<25	<25	<25	<25	0%
Chloromethane		<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%
Ethylbenzene	2900	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%
Naphthalene	0.02	<25	<25	38	<25	<25	<25	<25	<25	94	<25	0%
Tetrachloroethene		<25	<25	<25	<25	38	<25	<25	<25	<25	<25	0%
Toluene	1500	<25	<25	58	41	54	<25	<25	<25	53	<25	0%
1,2,4-Trimethylbenzene		<25	<25	<25	<25	<25	<25	<25	<25	41	<25	0%
1,3,5-Trimethylbenzene		<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%
Xylene, -o	4100*	<25	<25	<25	<25	<25	<25	<25	<25	41	<25	0%
Xylenes, -m, -p	4100*	<25	<25	<25	<25	<25	<25	<25	<25	65	<25	0%
Total Metals (mg/kg)												
Mercury		0.021	0.035	0.025	0.19	0.15	0.31	0.066	0.45	0.12	0.11	50%
Cadmium	8	0.2	0.11	0.13	0.64	0.38	0.97	0.96	0.5	0.17	0.41	58%
Chromium, Hexavalent	14	<1.6	<1.6	<1.7	<1.7	<1.8	<1.8	<1.7	<1.8	<1.8	--	0%
Chromium	16,000	7.2	5.7	6.4	27	19	42	23	12	8.4	20	23%
Lead	50	15	7.9	4.7	25	17	40	**1100**	**73**	29	14	62%
Special Analytical Services												
Solids, percent (%)		67.9	64.7	78.7	61.1	71.7	48.8	48.5	46.8	72	69.5	5%
TOC as NPOC (mg/kg)		9500	15000	5200	41000	18000	70000	110000	190000	88000	30000	45%

Notes:
"<" indicates parameter was not detected above specific laboratory detection limit
^ = VOC list does not include all parameters reported as below laboratory detection limits
* = Value listed for total analyte
0.0 = Exceeds Residual Contaminant Levels (RCLs) suggested for soil cleanup levels
RCLs listed for PAHs are non-industrial direct contact pathway values suggested in Table 1, Soil Cleanup Levels for PAHs Interim Guidance (WDNR, 1997)
RCLs listed for VOCs are groundwater protection values listed in Table 1, NR720 Soil Cleanup Standards, Wisc Adm Code
RCLs listed for metals are non-industrial direct contact pathway values listed in Table 2, NR720 Soil Cleanup Standards, Wisc Adm Code
Compiled by: gc Checked by: jm

Table 3
Sediment Analytical Results
Hog Island Inlet

Analytical Parameters	Level II SQT (PEC)	Level I SQT (TEC)	Lab Control	Risk Assessment Reference		Not Visually Contaminated but Secondary Contaminant Characteristics (Odor, FID)												Visually Contaminated Samples					Relative Percent Difference for	
			Sample No./Depth (ft)/Date																					
			ERA Lab Control - W.Bearskin Lake** 9/10/02	Loons Foot Landing Reference WL-2** 0-.5' 9/10/02	Loons Foot Landing Reference WL-2 0-.5' 10/2/02	Loons Foot Landing Reference WL-2 0-3' 10/2/02	HI-1** 0-.5' 9/10/02	HI-1 0-.5' 10/2/02	HI-1 0-3' 10/2/02	HI02-1 0-.5' 10/3/02	HI02-1 0-3' 10/3/02	HI02-10 0-.5' 10/3/02	HI02-10 0-3' 10/3/02	HI-27** 0-.5' 9/10/02	HI-27-DUP** 0-.5' 9/10/02	HI-27 0-.5' 10/2/02	HI-27 0-4' 10/2/02	HI02-77 0-.5' 10/2/02	HI02-77-DUP 0-.5' 10/2/02	HI02-77 0-3' 10/2/02	HI-13** 0-.5' 9/10/02	HI-13 0-.5' 10/2/02	HI-13 0-4' 10/2/02	HI02-24 0-.5' 10/2/02	HI02-24 0-3' 10/2/02	HI-27-DUP 0-.5' 9/10/02	HI02-77A-DUP 0-.5' 10/2/02
DRO (mg/kg)			<13	<6.8	13	6.7	13	12	6.6	<4.7	<4.4	80	56	21	<10	34	22	8.5	18	7.5	50	120	97	140	320	80%	72%
PAHs** (ug/kg)																										
* Acenaphthene	89	6.7	0.598	37.1	<29	<25	33.4	<66	<27	<21	<20	<57	<61	37.4	32.1	<91	<64	<69	<67	<58	182	<92	<73	<83	100	15%	0%
* Acenaphthylene	130	5.9	0.847	16.5	<22	<19	28.7	<50	<21	<16	<15	<43	83	49.4	42.8	<69	52	<52	<51	<44	90.8	100	70	<63	240	14%	0%
* Anthracene	850	57	1.95	89.8	<21	<18	115	<48	28	<15	<15	48	190	172	151	<66	73	<50	<48	58	441	110	69	180	210	13%	0%
* Benzo(a)Anthracene	1100	110	4.9	189	<24	34	229	84	79	<17	<17	110	310	322	288	82	220	<57	60	150	688	280	170	460	1000	11%	5%
* Benzo(a)Pyrene	1500	150	5.5	153	<22	22	228	77	60	<16	<15	77	270	396	351	85	190	<52	52	110	684	250	130	600	780	12%	0%
Benzo(b)Fluoranthene			12.9	154	<19	22	242	71	56	<14	<14	74	250	454	386	84	190	<46	45	110	761	270	130	610	700	16%	2%
Benzo(k)Fluoranthene			--	--	<23	22	--	77	58	<16	<16	71	230	--	--	79	180	<55	<53	110	--	220	100	540	760		0%
Benzo(g,h,i)perylene			14	96.1	<20	<17	165	62	37	<14	<14	50	150	305	268	<63	120	<48	<46	66	470	160	87	330	340	13%	0%
* Chrysene	1300	170	11.1	223	<24	30	341	99	79	<17	<17	130	630	619	550	130	260	57	62	140	1210	400	200	650	970	12%	8%
* Dibenzo(a,h)Anthracene	140	33	--	--	<19	<16	--	<44	<18	<14	<14	<38	58	--	--	<60	<43	<46	<44	<39	--	<62	<48	110	120		0%
* Fluoranthene	2200	420	17.2	476	23	73	443	190	210	<13	<13	120	770	584	500	160	370	89	140	410	1340	470	300	900	1400	15%	45%
* Fluorene	540	77	4.15	71.3	<22	<19	92.7	<50	23	<16	<15	62	120	149	128	<69	56	<52	<51	50	637	130	130	160	450	15%	0%
Indeno(1,2,3-cd)Pyrene			--	--	<20	<17	--	51	33	<14	<14	<40	130	--	--	<63	110	<48	<46	59	--	130	72	290	330		0%
1-Methylnaphthalene			--	--	<25	<21	--	<56	<23	<17	<17	190	200	--	--	<77	87	<59	<57	<49	--	360	240	250	710		0%
* 2-Methylnaphthalene	200	20	--	--	<21	<18	--	<48	33	<15	<15	260	290	--	--	<66	110	<50	<48	53	--	460	170	180	220		0%
* Naphthalene	560	180	4.24	100	<30	<25	151	<68	36	<21	<21	130	190	186	175	<93	100	<71	<69	<60	792	210	99	110	150	6%	0%
* Phenanthrene	1200	200	11.3	306	<19	56	312	91	120	<14	<14	170	420	378	322	79	240	47	78	230	1790	410	360	520	1200	16%	50%
* Pyrene	1500	200	11.2	429	25	79	472	150	170	<15	<15	150	490	729	635	160	400	77	110	300	1580	560	280	900	1600	14%	35%
* TPAH (13)	23,000	1,600	73	2,091	48	294	2,853	952	1,022	0	0	1,257	3,821	3,552	3,175	696	2,071	270	502	1,501	9,435	3,380	1,978	4,770	8,440	11%	60%
TPAH			100	2,341	48	338	2,446	691	838	0	0	1,642	4,781	4,281	3,829	859	2,758	270	547	1,846	10,666	4,520	2,607	6,790	11,280		
VOCs (ug/kg)***																										
Benzene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Carbon Tetrachloride			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Chloroform			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Chloromethane			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Ethylbenzene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Naphthalene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Tetrachloroethene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Toluene			<25	<25	<25	41	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	52	58	<25	<25	<25	<25	67	0%	70%
1,2,4-Trimethylbenzene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	100	0%	0%
1,3,5-Trimethylbenzene			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	60	0%	0%
Xylene, -o			<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	0%	0%
Xylenes, -m, -p			<25	<25	<50	<50	<25	<50	<50	<50	<50	<50	<50	<25	<25	<50	<50	<50	<50	<50	<25	<50	<50	<50	100	0%	0%
Metals (mg/kg)																										
Antimony	25	2	<0.9	<0.51	--	--	<0.55	--	--	--	--	--	--	1	0.94	--	--	--	--	--	<0.83	--	--	--	--	6%	--
Mercury	1.1	0.18	0.062	0.13	0.13	0.14	0.22	0.29	0.31	<0.0019	<0.0018	0.085	0.31	0.31	0.35	0.37	0.35	0.21	0.21	0.2	0.36	0.27	0.43	0.45	0.91	12%	0%
Arsenic	33	9.8	3.5	1.8	--	--	2.6	--	--	--	--	--	--	4.5	3.5	--	--	--	--	--	4.3	--	--	--	--	25%	--
Beryllium			0.38	0.45	--	--	0.59	--	--	--	--	--	--	0.83	0.76	--	--	--	--	--	0.82	--	--	--	--	9%	--
Cadmium	5	0.99	0.76	0.34	0.54	0.49	0.6	0.97	0.87	<0.087	<0.086	0.44	0.55	0.98	0.86	1.8	1	0.7	0.81	0.66	0.81	1.2	1	1.2	1.1	13%	15%
Chromium, Hexavalent			--	--	<1.7	<1.7		<1.7	<1.7	<1.7	<1.7	<1.6	<1.6			<1.8	<1.7	<1.7	<1.7	<1.7		<1.6	<1.8	<1.7	1.8		0%
Chromium	110	43	19	16	24	26	26	40	38	3.1	3.2	17	50	45	41	61	48	32	34	32	45	56	47	71	47	9%	6%
Copper	150	32	29	18	--	--	34	--	--	--	--	--	--	63	54	--	--	--	--	--	61	--	--	--	--	15%	--
Iron	40000	20000	31000	14000	--	--	17000	--	--	--	--	--	--	24000	22000	--	--	--	--	--	24000	--	--	--	--	9%	--
Lead	130	36	17	11	13	15	23	27	27	1.4	1.8	16	18	38	33	44	35	23	23	20	44	57	45	70	84	14%	0%
Manganese	1100	460	850	210	--	--	230	--	--	--	--	--	--	310	280	--	--	--	--	--	280	--	--	--	--	10%	--
Nickel	49	23	31	14	--	--	21	--	--	--	--	--	--	28	25	--	--	--	--	--	24	--	--	--	--	11%	--
Selenium			<1	<0.49	--	--	0.91	--	--	--	--	--	--	2.3	1.8	--	--	--	--	--	2.3	--	--	--	--	24%	--
Silver	2.2	1.6	<0.23	<0.13	--	--	<0.14	--	--	--	--	--	--	0.21	<0.16	--	--	--	--	--	0.3	--	--	--	--	27%	--
Zinc	460	120	79	52	--	--	110	--	--	--	--	--	--	190	170	--	--	--	--	--	180	--	--	--	--	11%	--
Simultaneous Extracted Metals (SEM)																											
Zinc - SEM (umole/g)			1.42	0.719	0.741	0.879	1.54	1.64	1.09	0.0542	0.147	1.15	1.14	2.72	2.57	2.54	1.54	1.66	2.08	0.922	2.98	2.99	1.76	3.59	2.42	0.06	0.22
Nickel - SEM (umole/g)			0.45	0.078	0.0796	0.0829	0.0872	0.1	0.0964	<0.00357	0.00654	0.0766	0.121	0.122	0.124	0.121	0.114	0.182	0.102	0.0908	0.156	0.14	0.128	0.18	0.12	0.02	0.56
Mercury - SEM (umole/g)			<0.000066	<0.000033	<0.000027	<0.000023	0.000286	<0.000031	<0.000025	<0.000019	<0.000019	<0.000026	<0.000028	<0.000048	0.00312	<0.000042	<0.000030	<0.000032	<0.000031	<0.000027	<0.000057	<0.000043	0.000124	0.000134	<0.000028	high	0.00
Lead - SEM (umole/g)			0.0787	0.0539	0.0558	0.0477	0.0903	0.11	0.11	0.00888	0.00616	0.154	0.129	0.163	0.151	0.163	0.154	0.0986	0.094	0.0757	0.249	0.232	0.19	0.313	0.282	0.08	0.05
Copper - SEM (umole/g)			0.353	0.15	0.157	0.142	0.158	0.283	0.326	0.0159	0.0271	0.283	0.258	0.471	0.427	0.441	0.296	0.243	0.235	0.21	0.393	0.471	0.382	0.618	0.267	0.10	0.03
Cadmium - SEM (umole/g)			0.00525	0.00264	0.00332	0.00228	0.00453	0.00524	0.00456	<0.00022	<0.000216	0.00297	0.00531	0.00661	0.00646	0.00667	0.00768	0.00418	0.0039	0.00299	0.00614	0.00871	0.00534	0.00697	0.00545	0.02	0.07
Total SEM (umole/g)			2.31	1	1.04	1.15	1.88	2.14	1.63	0.0828	0.187	1.67	1.65	3.48	3.28	3.27	2.11	2.19	2.51	1.3	3.78	3.84	2.46	4.71	3.09	0.06	0.14
Acid Volatile Sulfide (AVS) (umole/g)			8.2	2.1	2.6	0.11	11	1.7	0.062	0.046	0.046	2.2	0.35	11	9.8	0.89	1.5	5	3.3	0.28	34	11	1	23	23	0.12	0.41
SEM - AVS (umole/g)	120	1.7	-5.89	-1.1	-1.56	1.04	-9.12	0.44	1.57	0.04	0.14	-0.53	1.30	-7.52	-6.52	2.38	0.61	-2.81	-0.79	1.02	-30.22	-7.16	1.46	-16.29	-19.91		
Solids, percent (%)			28.8	53.9	56.6	66.9	48.6	50	60.2	80.2	81.4	58	53.9	36.1	37.5	36.4	51.5	47.7	49.5	56.7	32.7	35.7	45.4	39.8	54.6	0.04	0.04
TOC as NPOC (mg/kg)			43000	26000	25000	15000	45000	28000	26000	240	270	160000	53000	46000	63000	52000	46000	34000	71000	22000	100000	64000	40000	55000	84000	0.31	0.70
Oil & Grease, total recoverable (mg/kg)			<110	180	360	<110	350	640	740	160	150	910	1200	330	220	480	740	680	600	580	190	1600	1600	2800	4600	0.40	0.13
Nitrogen, total Kjeldahl (mg/kg)			2100	1500	2100	1600	2100	2600	2100	75	60	2800	2600	3200	3900	3200	3100	2900	3300	1800	3500	4300	3400	4300	3500	0.20	0.13
Grain Size																											
%Clay			--	18.5%	15.5%	--	29.5%	--	--	--	--	18.0%	--	40.5%	--	--	--	16.0%	--		17.5%	--	--	32.0%		--	--
%Silt			--	53.9%	59.6%	--	44.8%	--	--	--	--	16.1%	--	41.3%	--	--	--	48.5%	--		38.3%	--	--	15.6%		--	--
%Sand			--	27.0%	24.9%	--	25.7%	--	--	--	--	64.8%	--	18.0%	--	--	--	31.4%	--		43.5%	--	--	51.1%		--	--
% Gravel			--	0.6%	0.0%	--	0.0%	--	--	--	--	1.1%	--	0.2%	--	--	--	2.1%	--		0.6%	--	--	1.3%		--	--

Notes:
** PAH compounds shown for sediment samples collected 9/10/02 does not include additional PAH and Homologues from expanded analysis. Complete list is provided in separate table and appendix.
***VOC list is not complete. Complete list of non-detected VOCs is provided in lab reports in appendices.
-- = Not analyzed for

0.0 = Exceeds Level I Sediment Quality Criteria (SQT) Threshold Effect Criteria (TEC)
0.0 = Exceeds Level II Sediment Quality Criteria (SQT) Probable Effect Criteria (TEC)
* SQT for TPAHs is total of 13 PAHs with asterisks
SQTs shown for all PAHs and the metals mercury, arsenic, cadmium, copper, lead, nickel, and zinc are Sediment Quality Targets for the Protection of Sediment Dwelling Organisms in the St Louis River Area of Concern (Crane 2001)
SQTs shown for metals antimony, iron, manganese, silver are Table 1 Draft Sediment Quality Guideline Values (WDNR January2002)
SQTs shown for SEM-AVS metals are from Equilibrium Partitioning Guidelines for the Protection of Benthic Organisms: Metals Matures (USEPA 2000c)

Compiled by: ggc Checked by: jm

Table 4
Sediment Expanded Hydrocarbon Analytical Results
Hog Island Inlet

	Lab Control	Reference	Sample No./Depth (ft)/Date				Relative Percent Difference for
Analyte (ug/kg)	West Bearskin Lake 9/10/02	WL-2 0-0.5' 9/10/02	HI-1 0-0.5' 9/10/02	HI-27 0-0.5' 9/10/02	HI-27 Duplicate 0-0.5' 9/10/02	HI-13 0-0.5' 9/10/02	HI-27 Duplicate 9/10/02
Acenaphthene	1	37	33	37	32	182	15%
Acenaphthylene	1	17	29	49	43	91	14%
Anthracene	2	90	115	172	151	441	13%
Benzo(a)anthracene	5	189	229	322	288	688	11%
Benzo(a)pyrene	6	153	228	396	351	684	12%
Benzo(b)fluoranthene	13	154	242	454	386	761	16%
Benzo(g,h,i)perylene	14	96	165	305	268	470	13%
Chrysene	11	223	341	619	550	1,210	12%
Dibenz(a,h)anthracene	2	25	43	82	75	134	8%
Fluoranthene	17	476	443	584	500	1,340	15%
Fluorene	4	71	93	149	128	637	15%
Indeno(1,2,3-cd)pyrene	14	96	171	315	274	465	14%
Naphthalene	4	100	151	186	175	792	6%
Phenanthrene	11	306	312	378	322	1,790	16%
Pyrene	11	429	472	729	635	1,580	14%
Decalin	4	3	4	6	5	0	21%
C1-Decalins	0	13	22	51	49	1,630	4%
C2-Decalins	0	30	78	220	207	2,830	6%
C3-Decalins	0	46	192	580	456	3,690	24%
C4-Decalins	0	57	293	842	689	3,730	20%
Benzo(b)thiophene	0	8	13	15	14	34	8%
C1-Benzothiophenes	0	5	16	29	27	232	7%
C2-Benzothiophenes	0	9	27	48	45	476	7%
C3-Benzothiophenes	0	10	25	43	39	653	9%
C4-Benzothiophenes	0	11	26	54	51	719	5%
C1-napthalenes	3	101	194	294	252	1,800	15%
C2-napthalenes	7	128	339	577	568	4,090	2%
C3-napthalenes	4	118	292	543	519	5,800	5%
C4-napthalenes	2	74	233	537	521	4,750	3%
Biphenyl	2	20	28	33	44	127	30%
Dibenzofuran	4	66	85	101	93	461	9%
C1-Fluorenes	4	37	62	87	77	1,360	11%
C2-Fluorenes	5	61	119	200	180	2,940	11%
C3-Fluorenes	0	70	190	372	322	3,550	14%
C1-phenanthrenes/anthracenes	7	190	288	431	385	4,060	11%
C2-phenanthrenes/anthracenes	10	182	407	734	652	6,170	12%
C3-phenanthrenes/anthracenes	2	144	525	1,130	989	5,760	13%
C4-phenanthrenes/anthracenes	3	146	485	1,160	1,030	3,720	12%
Dibenzothiophene	1	31	47	67	59	932	12%
C1-dibenzothiophenes	1	47	79	131	113	2,350	15%
C2-dibenzothiophenes	1	79	182	325	295	4,180	10%
C3-dibenzothiophenes	0	103	390	870	768	4,760	12%
C4-dibenzothiophenes	0	74	354	877	795	2,810	10%
C1-fluoranthenes/pyrenes	8	296	472	1,070	963	2,520	11%
C2-fluoranthenes/pyrenes	0	157	528	1,610	1,410	3,320	13%
C3-fluoranthenes/pyrenes	0	106	432	1,300	1,150	2,650	12%
C1-chrysenes	4	126	308	744	665	1,580	11%
C2-chrysenes	0	105	363	1,010	934	2,000	8%
C3-chrysenes	0	60	258	764	690	1,450	10%
C4-chrysenes	0	29	101	327	267	590	20%
Benzo(j,k)fluoranthene	12	163	230	371	338	553	9%
Benzo(a)fluoranthene	2	34	52	86	76	151	13%
Benzo(e)pyrene	9	133	229	443	399	721	10%
Perylene	139	178	268	367	331	357	10%
Benzo(b)fluorene	1	ND	51	84	72	ND	15%
Total Expanded Hydrocarbons	**350**	**5,712**	**11,354**	**23,309**	**20,717**	**100,771**	**12%**

Table 5
Surface Water Analtyical Results
Hog Island Inlet

Analytical Parameters	Chronic Water Quality Criteria			Location/Sampling Date							Relative Percent Difference
	(a) EPA NRWQC CCC	(b) EPA FCV	(c) ORNL PRG	HI02-29-D **Disturbed** 10/1/02	HI02-29-U Undisturbed 10/1/02	NC-MOUTH-D **Disturbed** 10/1/02	NC-MOUTH-U Undisturbed 10/1/02	NC-MOUTH-U Undisturbed Duplicate 10/1/02	WL-2-D **Disturbed** 11/20/02	WL-2-U Undisturbed 11/20/02	NC-MOUTH-U Undisturbed 10/1/02
PAHs (µg/l)											
Acenaphthene		55.9	23	0.13	<0.018	0.19	0.023	0.023	<0.018	<0.018	0%
Acenaphthylene		307		<0.038	<0.019	<0.057	<0.019	<0.019	<0.019	<0.019	0%
Anthracene		20.7	0.73	0.056	<0.02	0.17	<0.02	<0.02	<0.02	<0.02	0%
Benzo(a)Anthracene		2.23	0.027	**0.07**	<0.012	**0.16**	<0.012	<0.012	<0.012	<0.012	0%
Benzo(a)Pyrene		0.957	0.014	**0.039**	<0.014	**0.1**	<0.014	<0.014	<0.014	<0.014	0%
Benzo(b)Fluoranthene		0.677		0.049	<0.013	0.11	<0.013	<0.013	<0.013	<0.013	0%
Benzo(k)Fluoranthene		0.642		<0.038	<0.019	<0.057	<0.019	<0.019	<0.019	<0.019	0%
Benzo(g,h,i)Perylene		0.439		0.032	<0.016	0.075	<0.016	<0.016	<0.016	<0.016	0%
Chrysene		2.04		0.084	<0.014	0.23	<0.014	<0.014	<0.014	<0.014	0%
Dibenzo(a,h)Anthracene		0.283		<0.032	<0.016	<0.048	<0.016	<0.016	<0.016	<0.016	0%
Fluoranthene		7.11	6.16	0.15	<0.013	0.52	0.023	0.023	<0.013	<0.013	0%
Fluorene		39.3	3.9	0.18	<0.017	0.32	<0.017	0.017	<0.017	<0.017	0%
Indeno(1,2,3-cd)Pyrene		0.275		<0.042	<0.021	<0.063	<0.021	<0.021	<0.021	<0.021	0%
1-Methyl Naphthalene		75.4	2.1	0.46	<0.018	0.5	<0.018	0.022	<0.017	<0.017	20%
2-Methyl Naphthalene		72.2		0.046	<0.017	0.07	<0.017	0.019	0.019	<0.017	11%
Naphthalene		194	12	0.076	<0.024	<0.072	<0.024	<0.024	0.03	0.026	0%
Phenanthrene		19.1	6.3	0.32	<0.016	0.71	0.024	0.026	<0.016	<0.016	8%
Pyrene		10.1		0.13	<0.017	0.4	<0.017	<0.017	<0.017	<0.017	0%
TPAH				1.82	ND	3.56	0.07	0.13	0.049	0.026	
VOCs (µg/l)											
Benzene			130	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0%
Carbon Tetrachloride				<0.47	<0.47	<0.47	<0.47	<0.47	<0.47	<0.47	0%
Chloroform			28	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	0%
Chloromethane				<0.27	0.27	<0.27	<0.27	<0.27	<0.27	<0.27	0%
Ethylbenzene			7.3	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	0%
Naphthalene			12	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	0%
Tetrachloroethene			98	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	0%
Toluene			9.8	<0.84	<0.84	<0.84	<0.84	<0.84	<0.84	<0.84	0%
1,2,4-Trimethylbenzene				<0.69	<0.69	<0.69	<0.69	<0.69	<0.69	<0.69	0%
1,3,5-Trimethylbenzene				<0.64	<0.64	<0.64	<0.64	<0.64	<0.64	<0.64	0%
Xylene, -o			13	<0.73	<0.73	<0.73	<0.73	<0.73	<0.73	<0.73	0%
Xylenes, -m, -p			1.8	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	0%
Total Metals (ug/l)											
Cadmium	0.25			**1.1**	<0.14	0.19	0.14	<0.14	<0.14	**0.43**	0%
Chromium	74			52	1.5	4.1	0.94	0.93	3.7	1.2	1%
Chromium, hexavalent	11			<2	<2	<6	<2	<2	--	--	0%
Lead	2.5			**87**	1.1	**21**	0.77	0.68	**3.5**	0.89	12%
Mercury	0.77			0.49	<0.028	0.06	<0.028	<0.028	<0.028	<0.028	0%
Special Analytical											
Oil & Grease, total recoverable (mg/l)				<1.2	<1.2	3.1	<1.2	<1.2	1.7	2.4	0%
BOD (mg/l)				<6	<60 (11 - 19)**	<2	<6	<6	--	--	0%
COD (mg/l)				45	43	35	33	33	100	50	0%
Solids, total suspended (mg/l)				640	4	<10	<10	<10	3100	11	0%
TOC as NPOC (mg/l)				15	13	15	14	14	19	16	0%

-- = Not analyzed for

(a) = National Recommended Water Quality Criteria Continuous Concentration (USEPA 2002)
(b) = Final Chronic Values for Surface Water (USEPA 2000)
(c) = ORNL Surface Water Preliminary Remediation Goal based on Secondary Chronic Value (Efroymson, 1997)

0.0 = Exceeds Chronic Water Quality Criteria
* = Value listed is for Total Analyte
<60 (11-19)** estimated BOD concentration outside ideal range was 19 mg/l. Reanalyses past hold time was 11 mg/l.
Compiled by: ggc Checked by: jm

Table 6
Comparison of 2002 Results to 1993 and 1994 Results
Hog Island Inlet

Analytical Parameters	Boring No./Depth (ft)/Date																				
	HI-1							HI-27							HI-13						
	HI-1**	HI-1	HI-1	HI-1	HI-1	HI-1	HI-1	HI-27**	HI-27-DUP**	HI-27	HI-27	HI-27	HI-27	HI-27	HI-13**	HI-13	HI-13	HI-13	HI-13	HI-13	HI-13	HI-13	HI-13
	0-0.5'	0-0.5'	0-3'	0 -0.4'	0.4 - 1'	0 -0.8'	0.8 - 1.2'	0-0.5'	0-0.5'	0-0.5'	0-4'	0 - 0.4'	0.4 - 1.7'	1.7' - 2.1'	0-0.5'	0-0.5'	0-4'	0 - 0.3'	0 - 0.3'	0.3 - 1.4'	0.3 - 1.4'	0 -1.7'	1.7 - 3'
	9/10/02	10/2/02	10/2/02	1993	1993	1994	1994	9/10/02	9/10/02	10/2/02	10/2/02	1994	1994	1994	9/10/02	10/2/02	10/2/02	1993	1993	1993	1993	1994	1994
Organics																							
Total PAHs (mg/kg)	2.9	1.0	1.0	2.1	2.9	3.9	3.7	3.6	3.2	0.7	2.1	2.4	3.4		9.4	3.4	2.0	4.8	2.7	5.4	5.4	5.4	3.5
DRO (mg/kg)	13	12	6.6	530	600	135	43	21	<10	34	22	237	210	6222	50	120	97	5610		3690		1764	296
TOC as NPOC (mg/kg)	45000	28000	26000	30300	31300	35000	28900	46000	63000	52000	46000	56000	40900		100000	64000	40000	47400	65800	32000	37770	47000	50000
Oil & Grease, total recoverable (mg/kg)	350	640	740	1200	920	1100	890	330	220	480	740	2100	1400		190	1600	1600	7000	9300	8000	4600	8500	1200
Metals (mg/kg)																							
Mercury	0.22	0.29	0.31	0.32	0.33	0.43	0.36	0.31	0.35	0.37	0.35	0.44	0.46		0.36	0.27	0.43	0.53	0.43	0.58	0.54	0.57	0.35
Chromium	26	40	38	25	26	40	40	45	41	61	48	43	41		45	56	47	52	54	38	65	49	37
Lead	23	27	27	23	21	36	36	38	33	44	35	41	38		44	57	45	64	70	62	61	81	100
Grain Size																							
% Fines	74%			80%	84%	89%	93%	82%				99%	95%		56%			79%		90%		85%	72%
Toxicity exhibited from bioassays?	weight reduction			not studied		not studied		possible weight reduction				no			survival and weight reductions			weight reductions				survival and weight reductions	
Degraded Macroinvertebrate Community?	yes			no				yes				yes			yes			yes				yes	

Table 7
Human Health Risk Assessment
Media Types and Location

Surface Soils	Surface Sediment	Surface Water – Disturbed & Undisdurted	Background		
			Surface Sediment	Surface Soil	Surface Water – Disturbed & Undisturbed
HIS-2	HI-1	HI-29-D	WL-2	WL-2A (SOIL)	WL-2-D
HIS-2-DUP	HI-13	NC-MOUTH-D			WL-2-U
HIS-4	HI-27	HI-29-U			
HIS-6	HI02-1A	NC-MOUTH-U			
HIS-7	HI02-10A				
HIS-9	HI02-24A				
HIS-13	HI02-77A				
HIS-18	HI02-77A-DUP				
HIS-21					
Compiled by: sd		Reviewed by: ggc			

Table 8
Human Health Risk Assessment
Chemicals of Potential Concern

Surface Soils	Surface Sediment	Surface Water - Disturbed
VOC 1,2,4-Trimethylbenzene Carbon tetrachloride Chloroform Naphthalene Styrene Tetrachloroethene Toluene Xylene, -o Xylenes, -m, -p	**VOC** Toluene Naphthalene	**VOC** Naphthalene
PAH 1-Methylnaphthalene* 2-Methylnaphthalene* Acenaphthylene* Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene* Benzo(k)fluoranthene Chrysene Fluoranthene Fluorene Indeno(1,2,3-cd)pyrene Naphthalene Phenanthrene* Pyrene	**PAH** 1-Methylnaphthalene* 2-Methylnaphthalene* Acenaphthylene* Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene* Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Fluorene Indeno(1,2,3-cd)pyrene Naphthalene Phenanthrene* Pyrene	**PAH** 1-Methylnaphthalene* 2-Methylnaphthalene* Acenaphthene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene* Chrysene Fluoranthene Fluorene Naphthalene Phenanthrene* Pyrene
METALS Cadmium Chromium Lead* Mercury	**METALS** Cadmium Chromium Lead* Mercury	**METALS** Cadmium Chromium Lead* Mercury

* = Toxocological values are not available and will be addressed qualitatively.

Compiled by: sd Reviewed by: ggc

Table 9
Human Health Risk Assessment
Potential Exposure Pathways

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future Recreational Shore Use	Surface Soil (0-1')	Surface Soil	Surface Soil	Adult	Adult	Dermal	Complete
				Adolescent	Ave. 12 yr.	Ingestion	Complete
		Air	Vapors and Particulates	Adult Adolescent	Adult Ave. 12 yr.	Inhalation	Complete
Current/Future Recreational Swimming and Wading	Surface Sediment (0-0.5')	Surface Sediment	Surface Sediment	Adult	Adult	Dermal	Complete
				Adolescent	Ave. 12 yr.	Ingestion	Complete
		Surface Water	Water at Hog Island Inlet	Adult	Adult	Dermal	Complete
				Adolescent	Ave. 12 yr.	Ingestion	Complete
		Air	Vapors and Particulates	Adult Adolescent	Adult Ave. 12 yr.	Inhalation	Complete
	Surface Water	Surface Water	Water at Hog Island Inlet	Adult	Adult	Dermal	Complete
				Adolescent	Ave. 12 yr.	Ingestion	Complete
		Air	Vapors and Particulates	Adult Adolescent	Adult Ave. 12 yr.	Inhalation	Complete
Current/Future Fish Ingestion	Fish Tissue	Fish Tissue	Digestive Tract	Adult Adolescent	Adult Ave. 12 yr.	Ingestion	Complete

Table 10

Summary of Human Health Risk Assessment Uncertainties

Uncertainty Factor	Effect of Uncertainty	Comment
Land Use Assumptions	May over- or underestimate risk	-zoning and land use policy could be altered changing exposure assumptions
Sampling and Analysis	May over- or underestimate risk	-sufficiency of sample collection is assumed
	May underestimate risk	-chemicals not included in laboratory analysis may cause underestimation of risk
	May over- or underestimate risk	-biases and random variability in data may not be representative of exposure concentrations
Exposure Point Concentrations	May overestimate risk	-steady state conditions at the source and exposure point are assumed resulting in overestimation of risk
	May underestimate risk	-degradation of chemicals to more toxic compounds may underestimate risk
		-Calculation of fish tissue concentrations using undisturbed water results may underestimate fish tissue concentrations and risk due to ingestion of the fish.
Mathematical Modeling	May overestimate risk	-simple equations used to predict complex intake conditions; equations generally considered conservative
	May over- or underestimate risk	-lack of site specific physical properties resulted in the use of default values which may not be representative
	May overestimate risk	-use of maximum analytical results considered conservative
Parameter Values	May overestimate risk	-EPA default values used at times; considered conservative
	May over- or underestimate risk	-professional judgement values follow EPA guidance and may not accurately reflect site use conditions
	May over- or underestimate risk	-media intake assumed to be constant
	May overestimate risk	-chromium assumed in the +6 oxidative state
Lack of toxicity values for some chemicals	May underestimate risk	-chemical not included in quantitative calculations
Toxicity values derived mainly from high dose and applied to low dose exposures	May over- or underestimate risk	-conservative exposure assumptions, assumes linearity at high and low dosage
Extrapolation from short-term studies to long-term exposures	May over- or underestimate risk	-conservative exposure assumptions
Extrapolation from animal studies to predict human response	May over- or underestimate risk	-species differ in rate of absorption, distribution, metabolism and elimination mechanisms
Extrapolation from occupational studies to the general population	May over - or underestimate risk	-population in general may be more varied than occupational population
Risk summation techniques	May over- or underestimate risk	-summation assumes independence of action by each chemical; discounts synergism, antagonism
	May overestimate risk	-SF are based on 95th percentile and not strictly additive
Toxicity value strength of support	May over-or underestimate risk	-weight-of-evidence may differ between chemicals

Table 11
Human Health Risk Assessment
Risk/Hazard Indices Summary – Adults

	Current & Future Recreational - Swimming		Current &Future Recreational – Wading		Current & Future Recreational – Shore Use		Current & Future Fish Ingestion		**Total Recreational Risk**	
	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI
Surface Soil	N/A	N/A	N/A	N/A	1.9 E-7	4.2 E-3	N/A	N/A	1.9 E-7	4.2 E-3
Surface Sediment	7.9 E-7	1.7 E-2	3.0 E-7	6.5 E-3	N/A	N/A	N/A	N/A	1.10E-06	2.40E-02
Surface Water	2.5 E-5	4.9 E-3	7.8 E-6	1.8 E-3	N/A	N/A	N/A	N/A	3.30E-05	6.70E-03
Fish Ingestion	N/A	N/A	N/A	N/A	N/A	N/A	3.2 E-9	2.3 E-2	3.2 E-9	2.3 E-2
Total	**3E-05**	**0.022**	**8E-06**	**0.0083**	**2E-07**	**0.0042**	**3E-9**	**0.023**	**3E-05**	**0.058**
Does risk exceed WI standard*?	**Yes**	**No**	**No**	**No**	**No**	**No**	**No**	**No**	**Yes**	**No**

* NR 720 Wisconsin Administrative Code acceptable cumulative cancer risk limit 1E-05 and the acceptable hazard index for non-carcinogens is less than 1.0.

Table 12
Human Health Risk Assessment
Risk/Hazard Indices Summary – Adolescents

	Current & Future Recreational - Swimming		Current &Future Recreational – Wading		Current & Future Recreational – Shore Use		Current & Future Fish Ingestion		Total Recreational Risk	
	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI	Carcinogenic Risk	Non-carcinogenic HI
Surface Soil	N/A	N/A	N/A	N/A	2.5 E-7	9.9 E-3	N/A	N/A	2.5 E-7	9.9 E-3
Surface Sediment	8.8 E-7	4.1 E-2	3.8 E-7	1.5 E-2	N/A	N/A	N/A	N/A	1.3E-06	5.6E-02
Surface Water	2.4 E-5	1.2 E-2	7.1 E-6	4.1 E-3	N/A	N/A	N/A	N/A	3.1E-05	1.6E-02
Fish Ingestion	N/A	N/A	N/A	N/A	N/A	N/A	2.0 E-9	3.6 E-2	2.0 E-9	3.6 E-2
Total	**2E-05**	**0.053**	**7E-06**	**0.019**	**3E-07**	**0.0099**	**2E-9**	**0.036**	**3E-05**	**0.11**
Does risk exceed WI standard*?	**Yes**	**No**	**No**	**No**	**No**	**No**	**No**	**No**	**Yes**	**No**

* NR 720 Wisconsin Administrative Code acceptable cumulative cancer risk limit 1E-05 and the acceptable hazard index for non-carcinogens is less than 1.0.

Table 13
2002 Ecological Risk Assessment Sediment Chemical Metrics
Hog Island Inlet

Site:	Lab Control West Bearskin Lake	Reference WL-2	HI-1	HI-27	HI-13
Sediment Chemical Concentrations:					
DRO (mg/kg)	<13	<6.8	13	21	50
% Diff from *Reference (assuming DRO = 6.8)*			91%	209%	635%
Subtotal 18 PAHs on WI list (ug/kg)	100	2,341	2,853	4,281	10,666
% Diff from *Reference*			22%	83%	356%
Total Expanded Hydrocarbons (PAHs & Homologues) (ug/kg)	350	5,712	11,354	23,309	100,771
% Diff from *Reference*			99%	308%	1664%
Sediment PEC-Q and ESGs TU's					
Number of Analytes exceeding a TEC	3	8	13	18	18
% Diff from *Reference*			63%	125%	125%
Number of Analytes exceeding a PEC	0	0	0	0	5
% Diff from *Reference*			0%	0%	500%
Mean PEC- Q (PAH and Metals)	0.10	0.11	0.16	0.24	0.37
% Diff from *Reference*			45%	118%	236%
PAH (37) ESG TU's	0.01	0.28	0.28	0.44	1.00
% Diff from *Reference*			3%	59%	263%
Grain Size: % fines		72%	74%	82%	56%
% Diff from *Reference*			3%	13%	-23%
TOC as NPOC (mg/kg)	43000	26000	45000	46000	100000
% Diff from *Reference*			73%	77%	285%

Table 14
2002 Ecological Risk Assessment Sediment Toxicity Test Results
Hog Island Inlet

Site:	Lab Control West Bearskin Lake	Reference WL-2	HI-1	HI-27	HI-13
***Hyalella azteca*, 28 day test using white light**					
Mean percent Survival	**90**	**60**	**75**	**86.3**	**65**
Standard Deviation	9.3	29.3	12	9.2	25.6
% Diff from *Control* Mean Survival*			-17% (p<.05)	-4%	-28% (p<.05)
Mean Weight/Individual (mg)	**0.208**	**0.211**	**0.137**	**0.168**	**0.188**
Standard Deviation	0.024	0.120	0.033	0.038	0.033
% Diff from *Reference* Mean Weight			-35% (p<.05)	-20% (p=.35)	-11%
***Hyalella azteca*, 28 day test using ultraviolet light**					
Mean percent Survival	**98.8**	**90**	**83.8**	**81.3**	**47.5**
Standard Deviation	3.5	9.3	16	15.5	17.5
% Diff from *Reference* Mean Survival			-7%	-10%	-47% (p<.05)
Mean Weight/Individual (mg)	**0.212**	**0.238**	**0.188**	**0.275**	**0.592**
Standard Deviation	0.022	0.097	0.035	0.068	0.196
% Diff from *Reference* Mean Weight			-21% (p<.05)	16%	149%
***Lumbriculus variegatus*, 10 day test using white light**					
Mean percent Survival	**97.5**	**98.8**	**97.5**	**88.8**	**62.5**
Standard Deviation	4.6	3.5	4.6	9.9	30.1
% Diff from *Reference* Mean Survival			-1%	-10%	-37% (p<.05)
Mean Weight/Individual (mg)	**1.653**	**1.691**	**1.454**	**1.556**	**1.268**
Standard Deviation	0.370	0.262	0.274	0.295	0.448
% Diff from *Reference* Mean Weight			-14%	-8%	-25% (p<.05)
***Lumbriculus variegatus*, 10 day test using ultraviolet light**					
Mean percent Survival	**93.8**	**98.8**	**100**	**93.8**	**13.8**
Standard Deviation	7.4	3.5	0	14.1	20
% Diff from *Reference* Mean Survival			1%	-5%	-86% (p<.05)
Mean Weight/Individual (mg)	**1.653**	**1.622**	**1.446**	**1.728**	**1.159**
Standard Deviation	0.324	0.195	0.217	0.441	0.392
% Diff from *Reference* Mean Weight			-11%	7%	-29% (p<.05)
***Chironomus tentans*, 10 day test using white light**					
Mean percent Survival	**95**	**90**	**91.2**	**91.2**	**95**
Standard Deviation	5.4	7.6	8.4	9.9	5.4
% Diff from *Reference* Mean Survival			1%	1%	6%
Mean Weight/Individual (mg)	**0.881**	**0.999**	**0.916**	**1.004**	**0.742**
Standard Deviation	0.087	0.095	0.123	0.108	0.131
% Diff from *Reference* Mean Weight			-8%	1%	-26% (p<.05)
***Chironomus tentans*, 10 day test using ultraviolet light**					
Mean percent Survival	**93.8**	**87.5**	**91.2**	**88.8**	**85**
Standard Deviation	5.2	10.4	11.3	13.6	10.7
% Diff from *Reference* Mean Survival			4%	1%	-3%
Mean Weight/Individual (mg)	**0.804**	**0.981**	**0.794**	**0.994**	**0.688**
Standard Deviation	0.11	0.143	0.152	0.233	0.108
% Diff from *Reference* Mean Weight			-19% (p<.05)	1%	-30% (p<.05)

Notes:
* Hyalella azteca 28 day White Light Test Survival Reduction was compared to control due to low survival in the reference site test.

Table 15
Ecological Risk Assessment Sediment MacroInvertebrate Survey Metrics
Hog Island Inlet

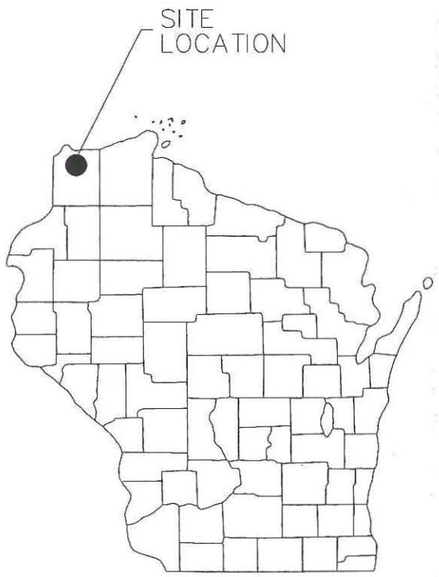
Site:	WL-Ref		HI-1			HI-27			HI-13		
	Mean	STD	**Mean**	STD	Sig Diff	**Mean**	STD	Sig Diff	**Mean**	STD	Sig Diff
Abundance of Organisms (/m^2)	**38,306**	5,531	**109,010**	44,220		**89,306**	20,648		**43,154**	13,044	
% Diff from Ref Site			185%		(p<.01)	133%		(p<.05)	13%		(p<.50)
Abundance Oligochaetes (/m^2)	**7,538**	3,670	**84,237**	36,097		**57,745**	17,253		**26,977**	9,603	
% Diff from Ref Site			1018%		(p<.001)	666%		(p<.01)	258%		(p<.01)
% Oligochaetes of Total	**19.6%**	8.3%	**76.6%**	4.0%		**64.7%**	9.8%		**62.5%**	14.2%	
% Diff from Ref Site			291%		(p<.001)	230%		(p<.001)	219%		(p<.001)
Abundance Chironomidae (/m^2)	**25,170**	6,711	**10,359**	2,990		**7,185**	5,085		**2,072**	1,309	
% Diff from Ref Site			-59%		(p<.001)	-71%		(p<.001)	-92%		(p<.001)
% Chironomidae of Total	**65.2%**	10.6%	**10.2%**	2.5%		**8.0%**	5.1%		**4.8%**	3.0%	
% Diff from Ref Site			-84%		(p<.001)	-88%		(p<.001)	-93%		(p<.001)
Chironomidae/Oligochaete Ratio	**3.99**	2.16	**0.13**	0.04		**0.14**	0.12		**0.08**	0.06	
% Diff from Ref Site			-97%		(p<.001)	-97%		(p<.001)	-98%		(p<.001)
Abundance Mollusca (/m^2)	**3,570**	754	**4,496**	2,106		**9,962**	3,040		**10,623**	6,684	
% Diff from Ref Site			26%		(p<.40)	179%		(p<.05)	198%		(p<.01)
% Mollusca of Total	**9.4%**	2.0%	**4.2%**	1.1%		**11.7%**	4.0%		**24.6%**	15.3%	
% Diff from Ref Site			-56%		(p<.01)	24%		(p<.30)	163%		(p<.05)
Abundance Amphipod Gamarus fasciatus (/m^2)	**1,322**	1,256	**9,521**	4,345		**13,885**	6,142		**2,953**	1,881	
% Diff from Ref Site			620%		(p<.05)	950%		(p<.001)	123%		(p<.15)
% Gammarus of Total	**3.9%**	3.8%	**8.7%**	2.4%		**15.0%**	4.4%		**6.8%**	4.4%	
% Diff from Ref Site			126%		(p<.05)	290%		(p<.01)	78%		(p<.30)
Shannon Diversity Index, SW H	**2.23**	0.27	**1.76**	0.09		**1.62**	0.36		**2.03**	0.15	
% Diff from Ref Site			-21%		(p<.05)	-28%		(p<.01)	-9%		(p<.10)
Shannon Evenness, SW E	**0.71**	0.07	**0.56**	0.06		**0.55**	0.09		**0.71**	0.06	
% Diff from Ref Site			-21%		(p<.001)	-23%		(p<.001)	-1%		(p<.001)
Biotic Index, BI	**7.2**	0.3	**9.2**	0.1		**8.9**	0.2		**8.5**	0.4	
% Diff from Ref Site			27%		(p<.001)	23%		(p<.001)	18%		(p<.001)
Taxa Richness	**23**	5	**24**	5		**19**	4		**18**	3	
% Diff from Ref Site			2%		(p<.95)	-20%		(p<.20)	-24%		(p<.10)
Taxa Richness (Composite of Replicates)	**40**		**42**			**32**			**32**		
% Diff from Ref Site			5%			-20%			-20%		
# of Species In Common with Reference Site (Composite)	**40**		**20**			**16**			**16**		
# of Species Not Common with Reference Site (Composite)	0		22			16			16		
Jaccard Coeff of Community	**1**		**0.32**			**0.29**			**0.29**		
% Diff from Ref Site			-68%			-71%			-71%		
Community Similarity Index	**100%**		**49%**			**44%**			**44%**		
% Diff from Ref Site			-51%			-56%			-56%		

Table 16
Integration of Measurement Endpoint Metrics for Assessing Impacts of Contaminated Sediments to the Benthic Community
Hog Island Inlet

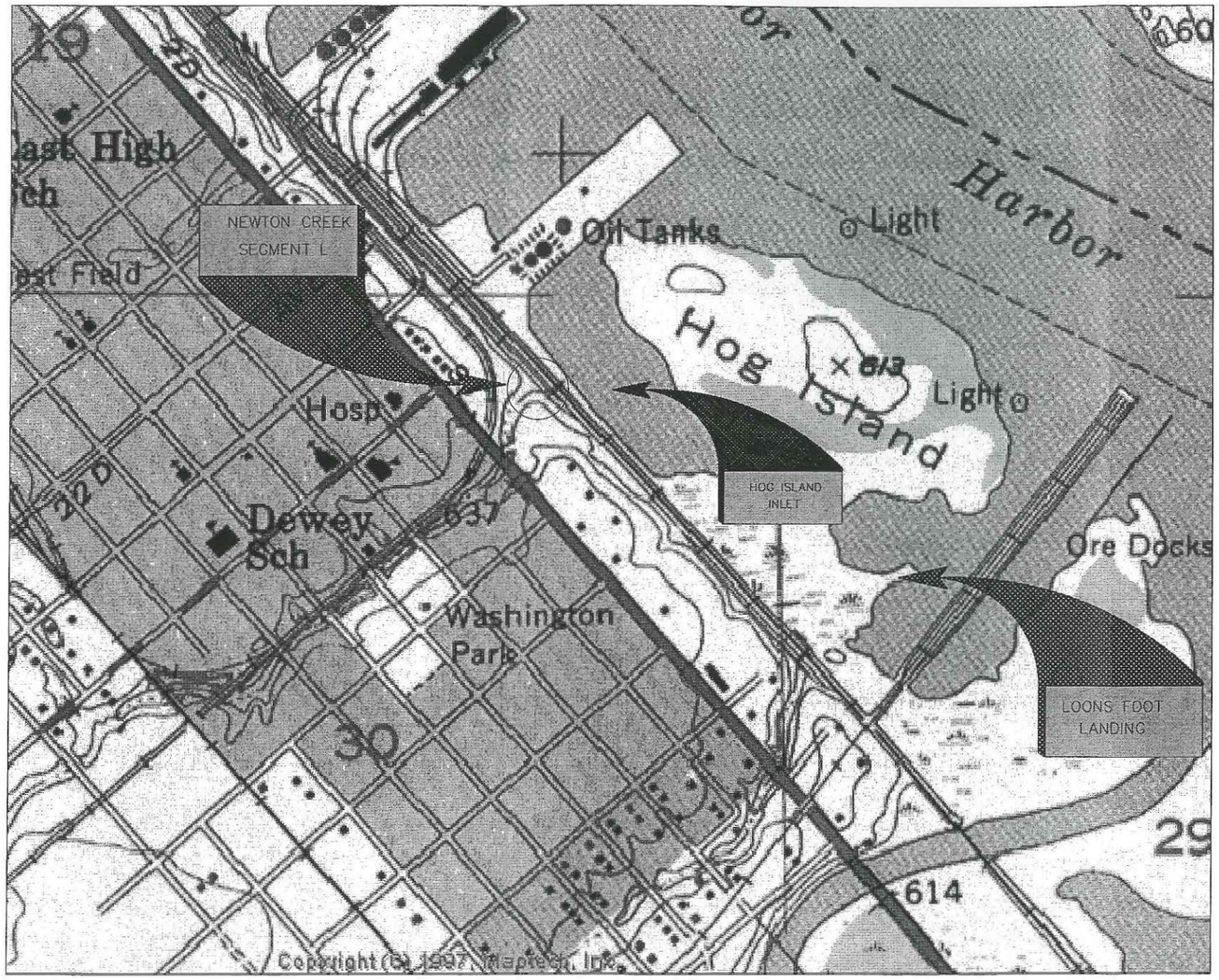
Location:	**HI-1** (WI TPAH = 2,853 ug/kg)	**HI-27** (WI TPAH = 4,281 ug/kg)	**HI-13** (WI TPAH = 10,666 ug/kg)	Hog Island Inlet Contaminated Sediments
Sediment Chemistry	+	+	+	+
+ if >20% Difference compared to reference	DRO, Total 18 PAHs on WI List, Total Expanded Hydrocarbons, Number of Analytes exceeding a TEC, Mean PEC-Q (PAHs and Metals)	DRO, Total 18 PAHs on WI List, Total Expanded Hydrocarbons, Number of Analytes exceeding a TEC, Mean PEC-Q (PAHs and Metals), PAH ESG Tus	DRO, Total 18 PAHs on WI List, Total Expanded Hydrocarbons, Number of Analytes exceeding a TEC, Number of Analytes exceeding a PEC, Mean PEC-Q (PAHs and Metals), PAH ESG Tus	Chemical data from sediments collected at multiple sites in WDNR 1993, 1994 and 2002 studies demonstrate impacts at some locations. Chemical data reported in technical literature ((Ankley et al 1994; Monson et al 1995, Kosian et al 1998, Diamond et al 2003) for sediment samples collected from Hog Island Inlet indicate impacts.
Review if 15% - 20%	none	none	none	
<15% Difference	Number of Analytes exceeding a PEC, PAH ESG Tus	Number of Analytes exceeding a PEC	none	
Sediment Toxicity Test	+	- / +	+	+
+ if >20% Difference compared to reference*	*Hyalella azteca* 28 day White Light Test Weight Reduction; *Hyalella azteca* 28 day UV Light Test Weight Reduction		*Hyalella azteca* 28 day White Light Test Survival Reduction (compared to control) ; *Hyalella azteca* 28 day UV Light Test Survival Reduction; *Lumbriculus variegatus* 10 day White Light Test Survival and Weight Reduction; *Lumbriculus variegatus* 10 day UV Light Test Survival and Weight Reduction; *Chironomus tentans* 10 day White Light Test Weight Reduction; *Chironomus tentans* 10 day UV Light Test Weight Reduction.	Toxicity data from WDNR 1993, 1994 and 2002 studies demonstrate impacts at some locations. Toxicity reported in technical literature for sediment (Ankley et al 1994; Monson et al 1995, Kosian et al 1998) or organisms (Diamond et al 2003) collected from Hog Island Inlet.
Review if 15% - 20% Difference or p > 0.05	*Hyalella azteca* 28 day White Light Test Survival Reduction (17% diff, p<.05); *Chironomus tentans* 10 day UV Light Test Weight Reduction (19% diff, p<.05).	*Hyalella azteca* 28 day White Light Test Weight Reduction (20% diff , p = 0.35)	none	
<15% Difference	*Hyalella azteca* 28 day UV Light Test Survival Reduction; *Lumbriculus variegatus* 10 day White Light Test Survival and Weight Reduction; *Lumbriculus variegatus* 10 day UV Light Test Survival and Weight Reduction; *Chironomus tentans* 10 day White Light Test Survival and Weight Reduction; *Chironomus tentans* 10 day UV Light Test Survival and Weight Reduction.	*Hyalella azteca* 28 day White Light Test Survival and Weight Reduction; *Hyalella azteca* 28 day UV Light Test Survival and Weight Reduction; *Lumbriculus variegatus* 10 day White Light Test Survival and Weight Reduction; *Lumbriculus variegatus* 10 day UV Light Test Survival and Weight Reduction; *Chironomus tentans* 10 day White Light Test Survival and Weight Reduction; *Chironomus tentans* 10 day UV Light Test Survival and Weight Reduction.	*Hyalella azteca* 28 day White Light Test Weight Reduction; *Hyalella azteca* 28 day UV Light Test Weight Reduction; *Chironomus tentans* 10 day White Light Test Survival Reduction; *Chironomus tentans* 10 day UV Light Test Survival Reduction.	
Benthic Community	+	+	+	+
+ if >20% Difference compared to reference	Abundance of Oligochaetes; % Oligochaetes of Total; Abundance of Chironomids; % Chironomids of Total; Chiro/Olig Ratio; % Mollusca of Total; Abundance of Gammarus; % Gammarus of Total; Shannon Diversity Index; Shannon Evenness Index; Biotic Index; Jaccard Coeff of Community; Community Similarity Index	Abundance of Oligochaetes; % Oligochaetes of Total; Abundance of Chironomids; % Chironomids of Total; Chiro/Olig Ratio; Abundance of Mollusca; Abundance of Gammarus; % Gammarus of Total; Shannon Diversity Index; Shannon Evenness Index; Biotic Index; Jaccard Coeff of Community; Community Similarity Index,	Abundance of Oligochaetes; % Oligochaetes of Total; Abundance of Chironomids; % Chironomids of Total; Chiro/Olig Ratio; Abundance of Mollusca; % Mollusca of Total; Jaccard Coeff of Community; Community Similarity Index	Sediment benthic community data from 1993, 1994, 2002 demonstrates impacts at some locations
Review if 15% - 20% Difference or p > 0.05	Abundance of Mollusca (26%diff, p<.40)	% Mollusca of Total (24% diff, p<.30) Taxa Richness (20% diff, p<.20)	Abundance of Gammarus (123%diff, p<.15); % Gammarus of Total (78% diff, p<.30); Biotic Index (18% diff, p<.001); Taxa Richness (24%diff, p<.10)	
<15% Difference	Taxa Richness	none	Shannon Diversity Index; Shannon Evenness Index;	
Tissue Chemistry				+
	no location specific data	no location specific data	no location specific data	Tissue concentrations reported in technical literature (Diamond, et al 2003; West et al 2001; Patnode, et al) for organisms collected from Hog Island Inlet.
Possible Conclusions	Impact highly likely. Contaminant presence leading to adverse biological effects related to degradation and alteration of benthic community structure evident.	Impact Likely: Benthic community degraded/altered by mixture of contaminants present, but toxicity tests not sensitive to chemicals present.	Impact highly likely. Contaminant presence leading to adverse biological effects related to degradation and alteration of benthic community structure evident.	**Impact highly likely. Contaminant presence leading to adverse biological effects related to degradation and alteration of benthic community structure evident; and, bioaccumulation of sediment-associated contaminants has the potential to adversely affect upper trophic level aquatic life and aquatic dependant wildlife.**

Notes:
* except for Hyalella azteca 28 day White Light Test Survival Reduction which was compared to control due to low survival in the reference site test.

SITE INVESTIGATION
HOG ISLAND INLET
SUPERIOR, WISCONSIN



COUNTY LOCATION MAP



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WISCONSIN – DOUGLAS CO. 7.5 MINUTE SERIES
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1	09/17/03	SITE INVESTIGATION REPORT	RJH	09/03	MJB	09/03			MJB	9/29/03

ENGINEERS ARCHITECTS PLANNERS

HOG ISLAND INLET - SUPERIOR, WISCONSIN
SITE INVESTIGATION REPORT

FIGURE 1
SITE LOCATION MAP

PROJ. NO. WDNR990502
DATE 09/17/03

1

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HOG ISLAND INLET - SUPERIOR, WISCONSIN
SITE INVESTIGATION REPORT

FIGURE 2
SEDIMENT AND SOIL
SAMPLING LOCATIONS

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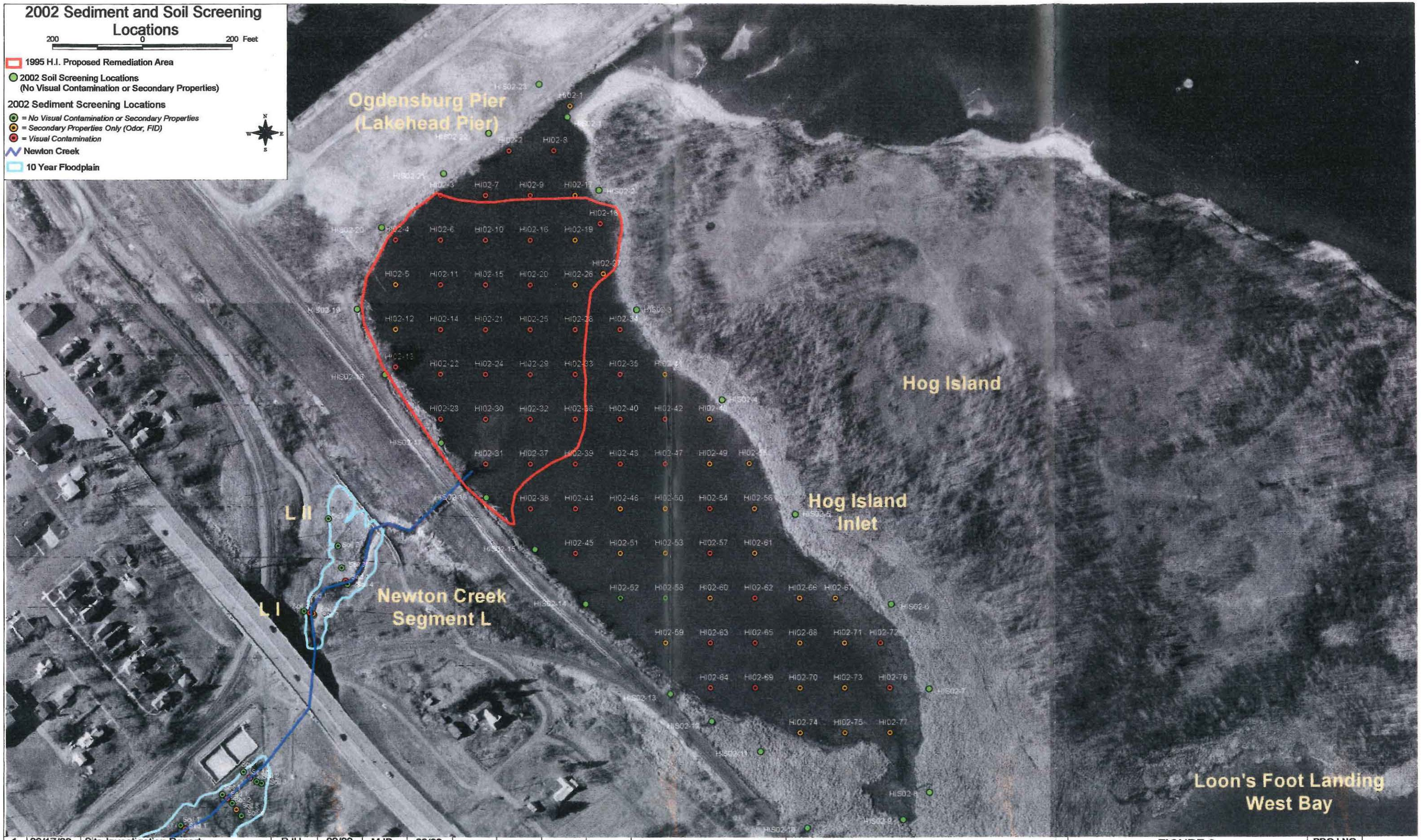
09/17/03

2



NO	DATE	ISSUE/REVISIONS	DRAWN BY		DESIGN		FIELD REVIEW	QC CHECK		
1	09/17/03	Site Investigation Report	RJH	09/03	MJB	09/03				

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HOG ISLAND INLET - SUPERIOR, WISCONSIN
SITE INVESTIGATION REPORT

FIGURE 3
2002 SEDIMENT AND SOIL SCREENING LOCATIONS

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09/17/03

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Comparison of Screening to Sampling Locations

200 0 200 Feet

- 1995 H.I. Proposed Remediation Area
- 2002 Soil Screening Locations

2002 Sediment Screening Locations

- = *No Visual Contamination or Secondary Properties*
- = *Secondary Properties Only (Odor, FID)*
- = *Visual Contamination*
- Newton Creek 1993 and 1994 Sediment Sampling Locations
- Hog Island Inlet 1993 and 1994 Sediment Sampling Locations
- Newton Creek
- 10 Year Floodplain

N W E S

NO	DATE	ISSUE/REVISIONS	DRAWN BY		DESIGN		FIELD REVIEW	QC CHECK
1	09/07/03	Site Investigation Report	RJH	09/03	MJB	09/03		

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HOG ISLAND INLET - SUPERIOR, WISCONSIN
SITE INVESTIGATION REPORT

FIGURE 4
COMPARISON OF SCREENING TO SAMPLING LOCATIONS

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09/17/03

4

Surface Water Sample Locations

200 0 200 Feet

1995 H.I. Proposed Remediation Area

2002 Surface Water Sample Locations

N
W E
S

HI02-29

NC-MOUTH

WL-2

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FIGURE 5
SURFACE WATER SAMPLING LOCATIONS

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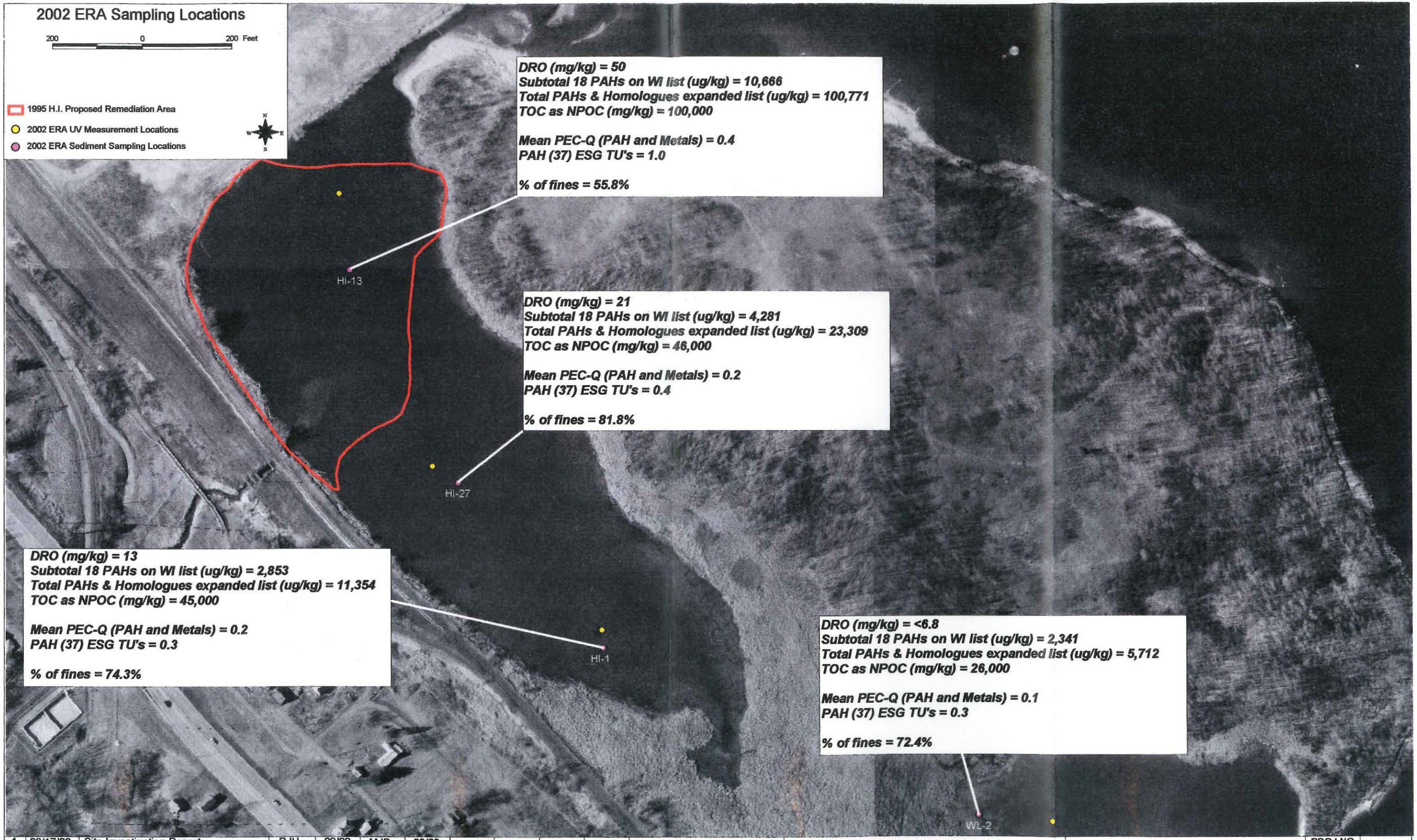

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FIGURE 6
2002 ERA SAMPLING LOCATIONS

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2002 TPAH and DRO Map

200 0 200 Feet

PAH = (ug/kg)

DRO = (mg/kg)

1995 H.I. Proposed Remediation Area

2002 Sampling Locations

HI02-1
HI02-1A: 0-0.5', 10/03/02, PAH = 0, DRO = <4.7
HI02-1A: 0-3', 10/03/02, PAH = 0, DRO = <4.4

HIS02-21
HIS02-21: 0-1', 10/03/02, PAH = 976

HIS02-2
HIS02-2: 0-1', 10/03/02, PAH = 843
HIS02-2DUP: 0-1', 10/03/02, PAH = 4,141

HI02-10
HI02-10A: 0-0.5', 10/03/02, PAH = 1,642, DRO = 80
HI02-10A: 0-3', 10/03/02, PAH = 4,781, DRO = 56

HI-13
HI-13: 0-0.5', 9/10/02, PAH = 10,666, DRO = 50
HI-13: 0-0.5', 10/02/02, PAH = 4,520, DRO = 120
HI-13: 0-4', 10/02/02, PAH = 2,607, DRO = 97

HIS02-18
HIS02-18: 0-1', 10/03/02, PAH = 1,601

HI02-24
HI02-24A: 0-0.5', 10/02/02, PAH = 6,790, DRO = 140
HI02-24A: 0-3', 10/02/02, PAH = 11,280, DRO = 320

HIS02-4
HIS02-4: 0-1', 10/03/02, PAH = 15

HI-27
HI-27: 0-0.5', 9/10/02, PAH = 4,281, DRO = 21
HI-27DUP: 0-0.5', 9/10/02, PAH = 3,828, DRO = <10
HI-27: 0-0.5', 10/02/02, PAH = 859, DRO = 34
HI-27: 0-4', 10/02/02, PAH = 2,758, DRO = 22

HIS02-6
HIS02-6: 0-1', 10/03/02, PAH = 53

HIS02-13
HIS02-13: 0-1', 10/03/02, PAH = 762

HI-1
HI-1: 0-0.5', 9/10/02, PAH = 2,853, DRO = 13
HI-1: 0-0.5', 10/02/02, PAH = 952, DRO = 12
HI-1: 0-3', 10/02/02, PAH = 1,022, DRO = 6.6

HIS02-7
HIS02-7: 0-1', 10/03/02, PAH = 525

HI02-77
HI02-77A: 0-0.5', 10/02/02, PAH = 270, DRO = 8.5
HI-77ADUP: 0-0.5', 10/02/02, PAH = 547, DRO = 18
HI-77A: 0-3', 10/02/02, PAH = 1,846, DRO = 7.5

HIS02-9
HIS02-9: 0-1', 10/03/02, PAH = 0

WL-2
WL-2: 0-0.5', 9/10/02, PAH = 2,341, DRO = 13
WL-2: 0-0.5', 10/02/02, PAH = 48, DRO = 6.7
WL-2: 0-3', 10/02/02, PAH = 338, DRO = <13

WL-2A
WL-2A: 0-0.5', 11/20/02, PAH = 642

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FIGURE 7
2002 TPAH and DRO Map

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2002 Sediment PEC-Q's and ESG's

200 0 200 Feet

PEC-Q = Mean PEC-Q (PAH & Metals)

ESG TU's for PAHs

1995 H.I. Proposed Remediation Area

2002 Sediment Sampling Locations

N W E S

HI02-1
HI02-1: 0-0.5', 10/03/02, ESG TU's = 0.0, PEC-Q = 0.0
HI02-1: 0-3', 10/03/02, ESG TU's = 0.0, PEC-Q = 0.0

HI02-10
HI02-10: 0-0.5', 10/03/02, ESG TU's = 0.1, PEC-Q = 0.1
HI02-10: 0-3', 10/03/02, ESG TU's = 1.2, PEC-Q = 0.2

HI-13
HI-13: 0-0.5', 9/10/02, ESG TU's = 1.0, PEC-Q = 0.4
HI-13: 0-0.5', 10/02/02, ESG TU's = 0.9, PEC-Q = 0.3
HI-13: 0-4', 10/02/02, ESG TU's = 0.9, PEC-Q = 0.2

HI02-24
HI02-24: 0-0.5', 10/02/02, ESG TU's = 1.6, PEC-Q = 0.3
HI02-10: 0-3', 10/02/02, ESG TU's = 1.8, PEC-Q = 0.4

HI-27
HI-27: 0-0.5', 9/10/02, ESG TU's = 0.4, PEC-Q = 0.2
HI-27: 0-0.5', 10/02/02, ESG TU'S = 0.2, PEC-Q = 0.2
HI-27: 0-4', 10/02/02, ESG TU's = 0.8, PEC-Q = 0.2

HI-1
HI-1: 0-0.5', 9/10/02, ESG TU's = 0.3, PEC-Q = 0.2
HI-1: 0-0.5', 10/02/02, ESG TU's = 0.4, PEC-Q = 0.1
HI-1: 0-3', 10/02/02, ESG TU's = 0.6, PEC-Q = 0.1

HI02-77
HI02-77: 0-0.5', 10/02/02, ESG TU's = 0.1, PEC-Q = 0.1
HI02-77: 0-3', 10/02/02, ESG TU's = 1.2, PEC-Q = 0.1

WL-2
WL-2: 0-0.5', 9/10/02, ESG TU's = 0.3, PEC-Q = 0.1
WL-2: 0-0.5', 10/02/02, ESG TU's = 0.0, PEC-Q = 0.1
WL-2: 0-3', 10/02/02, ESG TU's = 0.3, PEC-Q = 0.1

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FIGURE 8
2002 Sediment PEC-Q's and ESG TU's

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Figure 9-1

DRO vs. TPAH

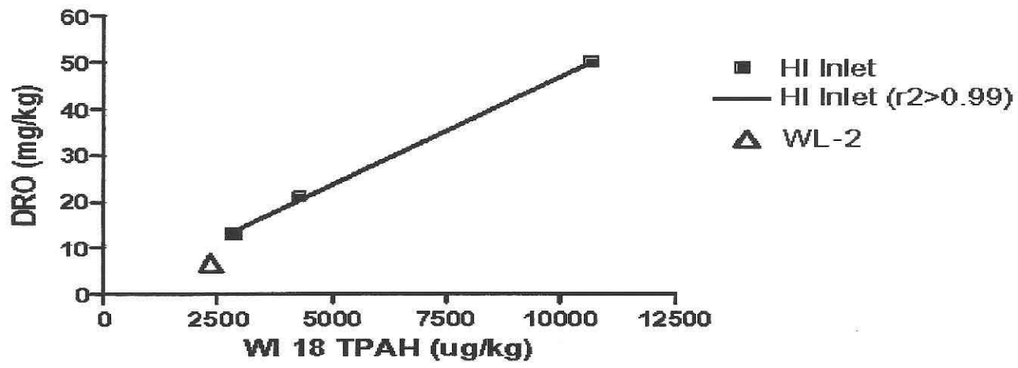

Figure 9-2

Total Expanded Hydrocarbons vs TPAH

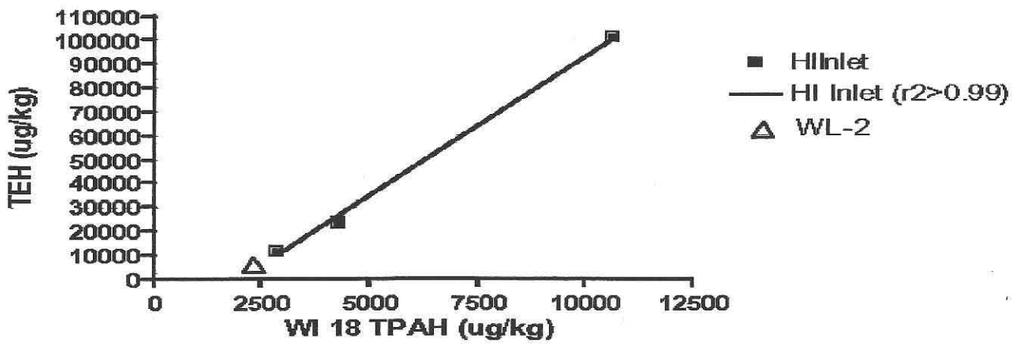

Figure 9-3

Mean PEC-Q (PAHs, metals) vs TPAH

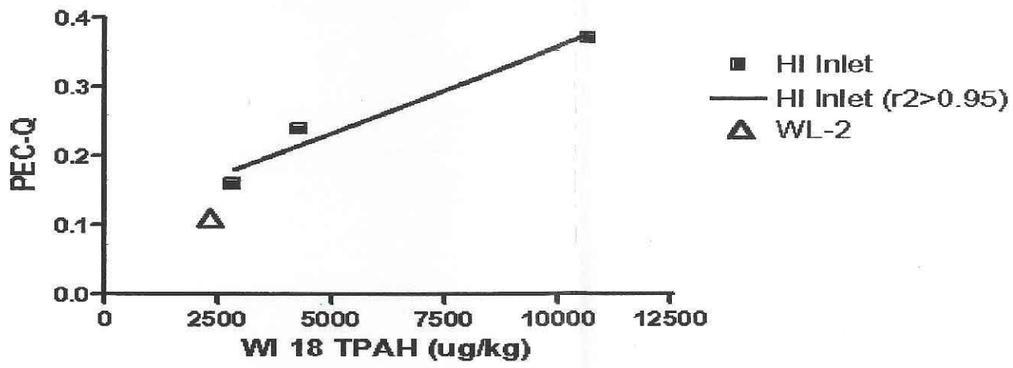

Figure 9-4

PAH ESG TUs vs TPAH

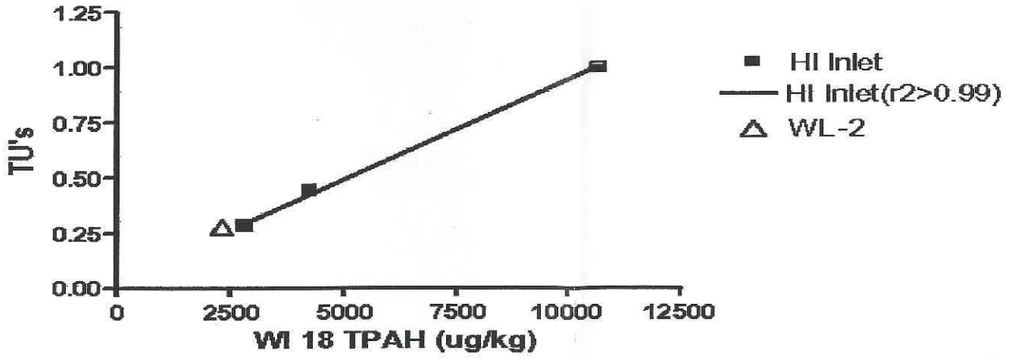

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FIGURE 9
Relationships of Sediment Chemistry to Sediment Quality Targets

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Figure 10-1

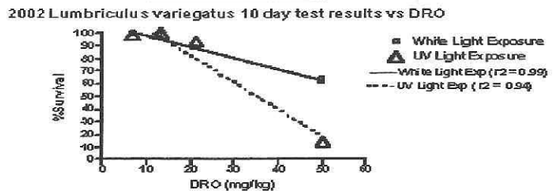

Figure 10-2

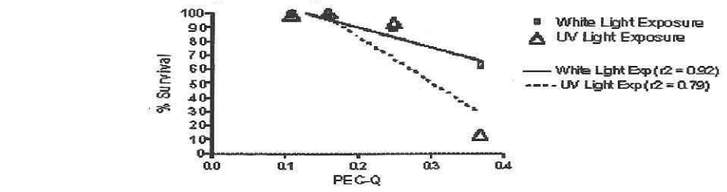

Figure 10-3

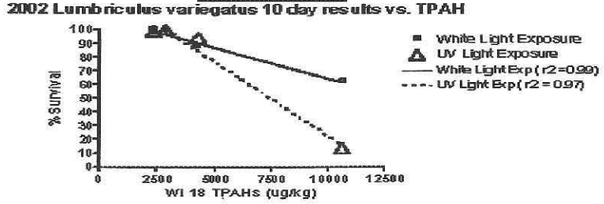

Figure 10-4

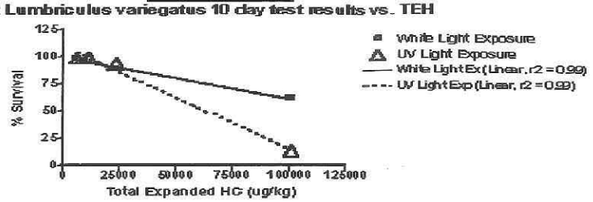

Figure 10-5

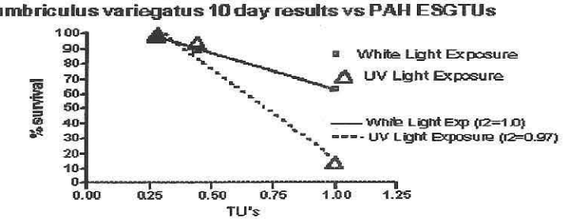

Figure 10-6

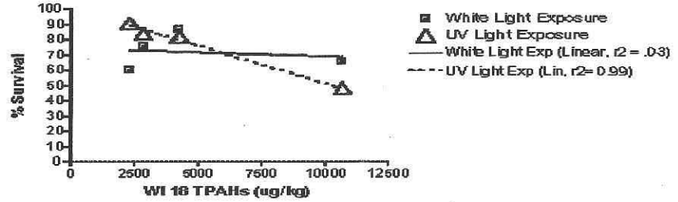

Figure 10-7

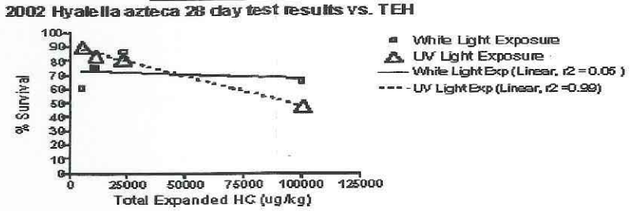

Figure 10-8

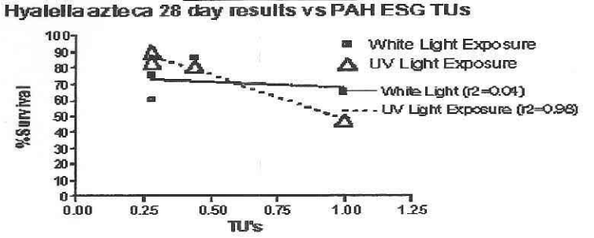

Figure 10-9

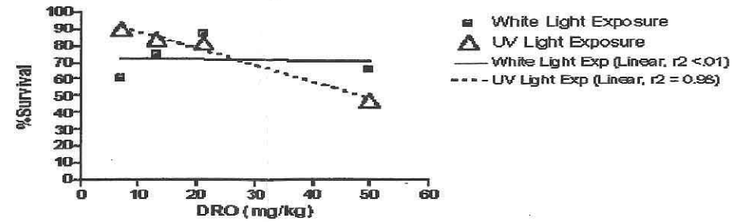

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FIGURE 10
Relationships of Sediment Chemistry to Ha and Lv Toxicity

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Figure 11-1

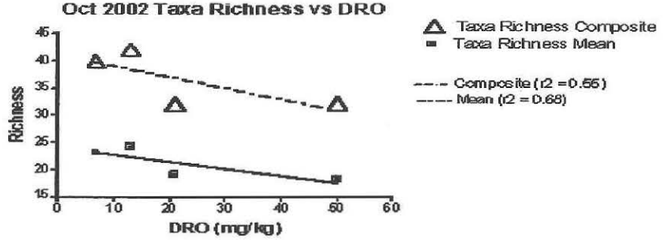

Figure 11-2

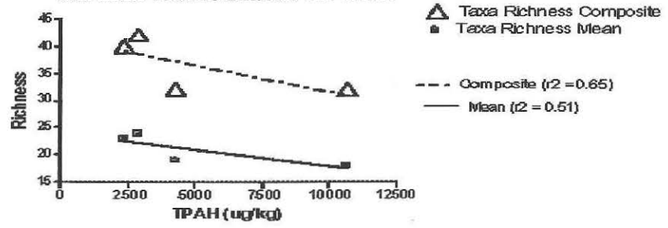

Figure 11-3

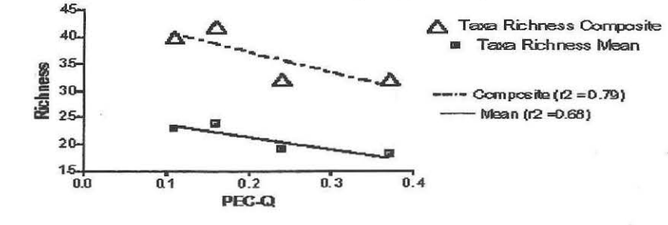

Figure 11-4

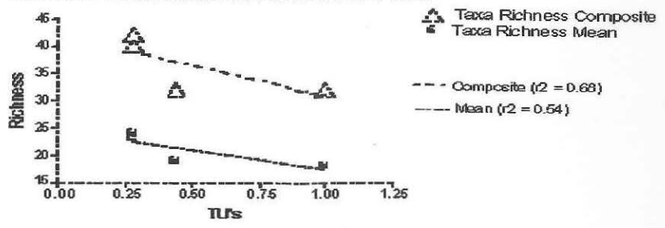

Figure 11-5

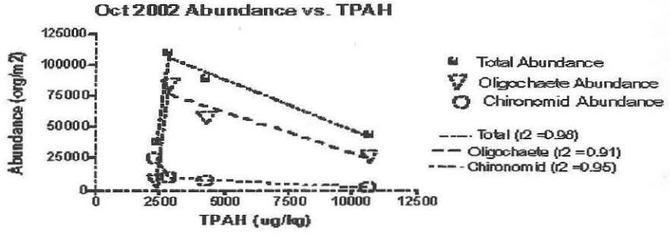

Figure 11-6

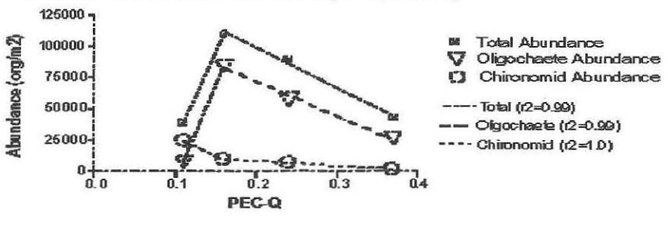

Figure 11-7

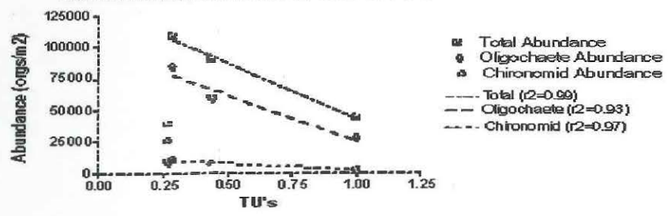

Figure 11-8

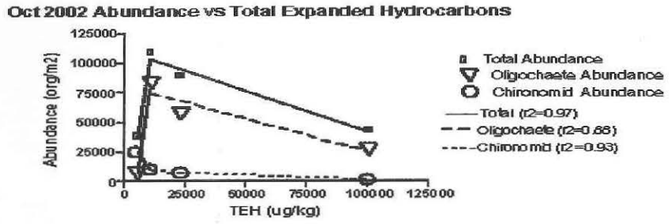

Figure 11-9

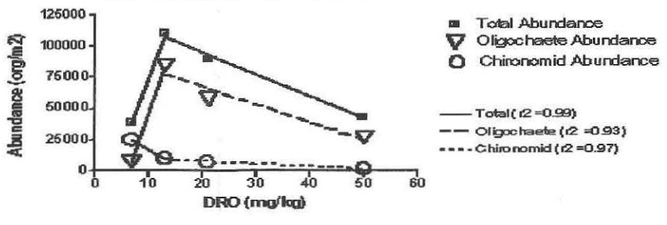

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FIGURE 11
Relationships of Sediment Chemistry to Benthic Macroinvertebrate Community Abundance and Taxa Richness

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